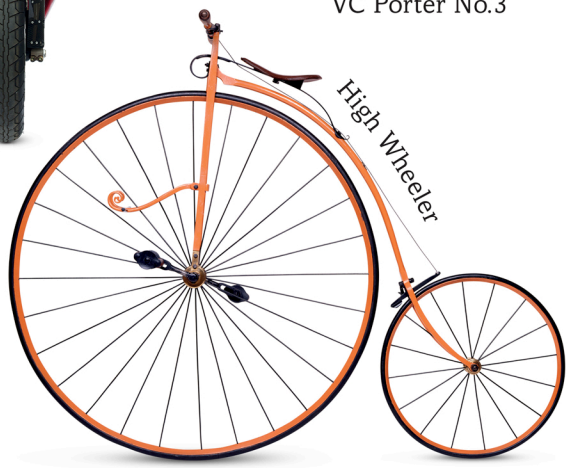
DK SMITHSONIAN

CARS, TRAINS, SHIPS & PLANES

A visual encyclopedia of every vehicle



CARS, TRAINS, SHIPS & PLANES

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Established in 1846, the Smithsonian Institution—the world's largest museum and research complex—includes 19 museums and galleries and the National Zoological Park. The total number of artefacts, works of art, and specimens in the Smithsonian's collection is estimated at 137 million, the bulk of which is contained in the National Museum of Natural History, which holds more than 126 million specimens and objects. The Smithsonian is a renowned research centre, dedicated to public education, national service, and scholarship in the arts, sciences, and history.

ABOUT THE AUTHOR

Clive Gifford is the winner of the Royal Society Young People's Book Prize and the School Library Association Information Book Award. He has written more than 150 books including **Wow! Science**, **Car Crazy**, and **Super Trucks**.

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A visual encyclopedia of every vehicle

WRITTEN BY **CLIVE GIFFORD**

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Foreword

Welcome to the world of fast cars and even faster planes, of mighty ships, awesome motorcycles, and heavy hauling trucks and trains. All these and many more machines that move people, goods, and materials can be found in this big book of transportation.

I have had a fascination with transportation for as long as I can remember. My father flew gliders and worked for an early airline company that offered many people their first taste of air travel. I remember him taking me to an air show when I was eleven to see an array of amazing aircraft—from massive jet bombers to nimble aerobatic biplanes. I found them astonishing, just as I did the giant trucks and two Ferrari supercars in the air show's parking lot. I was hooked and have remained excited by all forms of transportation ever since.

This book is packed with vehicles, craft, and vessels that have enabled people to travel farther, faster, and with greater ease—from the slickest street bike to the most powerful diesel train. Many have played their part in changing people's lives, and how and where they work and live. Before the development of modern cars, trains, ships, and planes, few people traveled outside

DHR Class B

De Dion-Bouton Type O

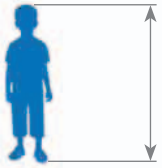
Bücker Bü133C Jungmeister

Montgolfier Hot-air Balloon

of their own neighborhood and even fewer traveled long distances overseas. Today, coast-to-coast journeys that once took weeks take hours, while you can cross the planet in less than a day on a giant jet airliner. Shipping now connects all parts of the globe, enabling you to buy food grown on the other side of the world and many other goods, too. Advances in transportation have helped people explore and settle new lands, make exciting discoveries about our world, and even blast off, leaving the planet altogether to explore the marvels of space.

Clive Gifford

Throughout this book you will find scale boxes that show the sizes of types of transportation compared to either a child or a school bus.



Child = 4 ft 9 in (1.45 m) tall

School bus = 36 ft (11 m) long

Unicycle

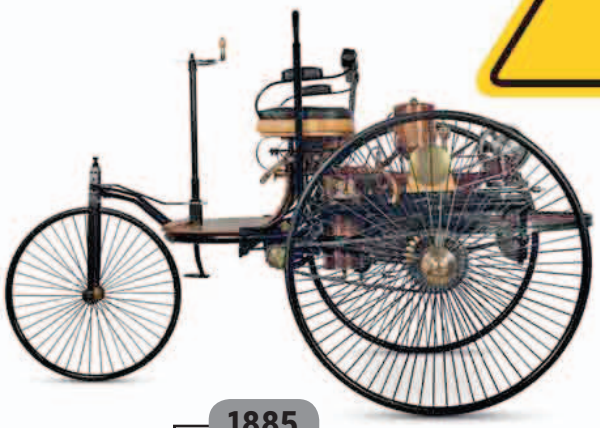
Sea-Doo® Spark™

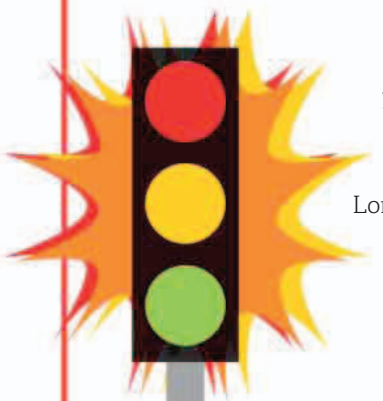
John Deere 650K XLT

On the road

The first automobile was a steam-powered cart that set off in 1769 at a top speed of 2.5 mph (4 km/h). Over the years, many clever inventions have helped shape modern motor vehicles. Today, more than one billion travel along the world's roads.

1769 French inventor Nicolas-Joseph Cugnot builds the first working automobile.





1868 The first traffic lights are installed in London. Not long afterward, they explode!

1876

German engineer Nikolaus Otto builds the first internal combustion engine.

1885

The Benz Motorwagen, the first wheeled vehicle powered by an internal combustion engine, takes to the road.

1927

The Napier-Campbell *Blue Bird* sets a land-speed record of 195 mph (314 km/h).

Blue Bird

1850

1900

1871

The High Wheeler, the first bicycle with big front wheels to boost speed, is designed.

1880

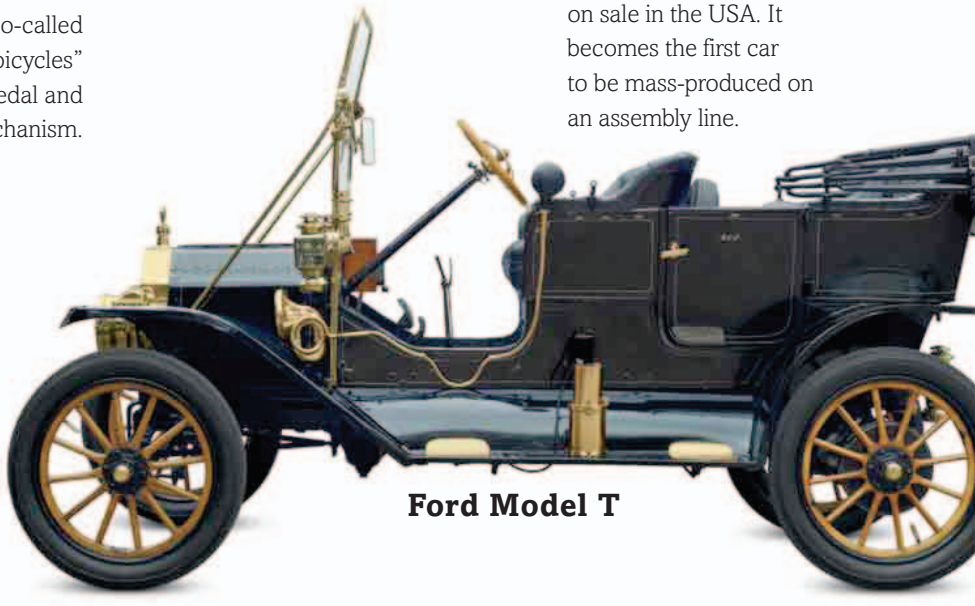
Several inventors develop so-called "safety bicycles" driven by a pedal and chain mechanism.

1894

In Germany, Hildebrand and Wolfmüller build the Motorrad, the first production motorcycle.

1908

The Ford Model T goes on sale in the USA. It becomes the first car to be mass-produced on an assembly line.



Ford Model T

1916 The first fully working armored tank, the Mark 1, goes into battle in France in World War I.

1979 Bigfoot, the first monster truck, is developed in the USA by Bob Chandler for off-road adventures.

2013 British company FlashPark invents a talking parking ticket.

1938

The Volkswagen Type 1, or Beetle, rolls off the production line in Germany. Over the years, a further 21.5 million are built.

1997

Thrust SSC sets a world land-speed record of 763 mph (1,228 km/h), faster than the speed of sound.

1950

The world's first Formula 1 World Championship is won by Italy's Giuseppe Farina in an Alfa Romeo 159.

1980

The world's longest recorded traffic jam of 105 miles (170 km) blocks roads in France.

1950

2000

1946

In Italy, Vespa produces its first scooter, sparking a fashion craze from the 1950s onward.

1981

Stumpjumper, the first mass-produced mountain bicycle, goes on sale in the USA.

2005

A Bugatti Veyron sets the record for the world's fastest production car, clocking 253 mph (407 km/h).

1940

The Jeep is first introduced as a general purpose light truck.

Jeep

Bugatti Veyron

1949 Sierra Sam becomes the first fully formed crash test dummy, used to test the safety features of cars.

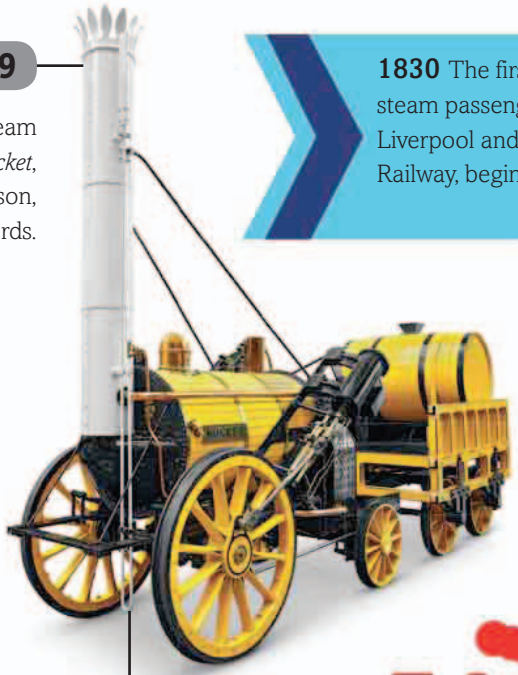
Along the tracks

Steam locomotives were known as "iron horses" when they started a transportation revolution in the early 1800s, speeding up the movement of people and goods all over the world. Today, diesel and electric locomotives have taken over from steam.

1770
Scottish inventor James Watt invents the compound steam engine, versions of which will power early locomotives.

1804
The *Pen-y-Darren* locomotive is built by British inventor Richard Trevithick, for work in mines.

1829
The first modern steam locomotive, the *Rocket*, built by Robert Stephenson, sets new speed records.



1830 The first intercity steam passenger service, the Liverpool and Manchester Railway, begins.

1863
The first underground city railroad, the Metropolitan Line, opens in London.

1869
The first Transcontinental Railroad across the USA is completed—a total of 1,907 miles (3,069 km) of tracks.

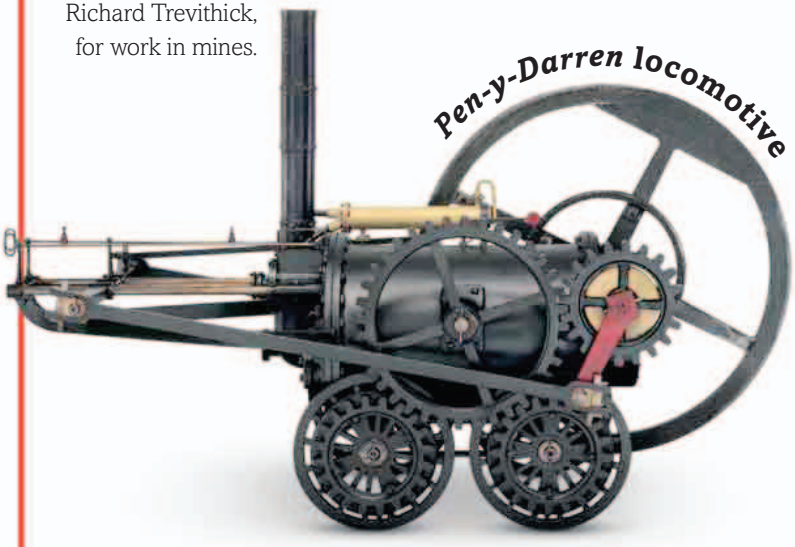
1881
The first electric streetcar service begins in Germany.

1906
The Simplon Tunnel, connecting Italy and Switzerland under the Alps, opens. It is the world's longest railroad tunnel.

1913
Grand Central Terminal opens in New York. The station has the most number of tracks—67 in all.

1914
Throughout World War I, railroads prove invaluable for moving troops and supplies.

1800 1850 1900



***Golden Eagle* Trans-Siberian Express**

1916

The world's longest railroad line, the Trans-Siberian Railway across Russia, is completed. It runs for 5,772 miles (9,289 km).

1937

German inventor Hermann Kemper develops magnetic levitation (maglev) as a force for moving trains.

1938

The *Mallard* sets the world record for the fastest-ever steam locomotive, at a speed of more than 125 mph (200 km/h).

1950

1955

Initial trials of the English Electric *Deltic*—the most powerful diesel locomotive in the world—take place.

1960

French Railways introduce the world's first 125 mph (200 km/h) service—the Le Capitole.

1964

The world's first bullet train, Shinkansen, connects Tokyo to other cities of Japan.

1975

In the UK, the Inter-City HST becomes the fastest diesel-powered train in the world.

1988 The world's longest underwater railroad tunnel, the Seikan Tunnel, 33.5 miles (53.9 km) long, is built to connect two Japanese islands.

1994
The high-speed Channel Tunnel Eurostar service begins from London to Paris.

1984

In the UK, the first commercial maglev transportation system opens, connecting Birmingham International Airport and nearby terminals.

2000

2007

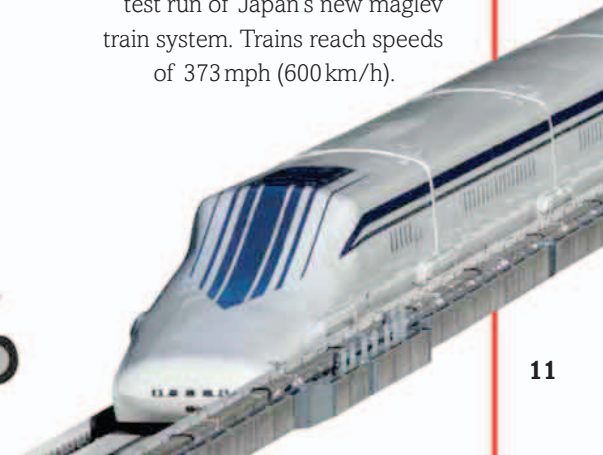
An experimental French TGV sets the world record for the fastest electric train, with a speed of 357 mph (574 km/h).

2012

Tokyo metro carries 3.29 billion passengers in a year, making it the busiest metro system in the world.

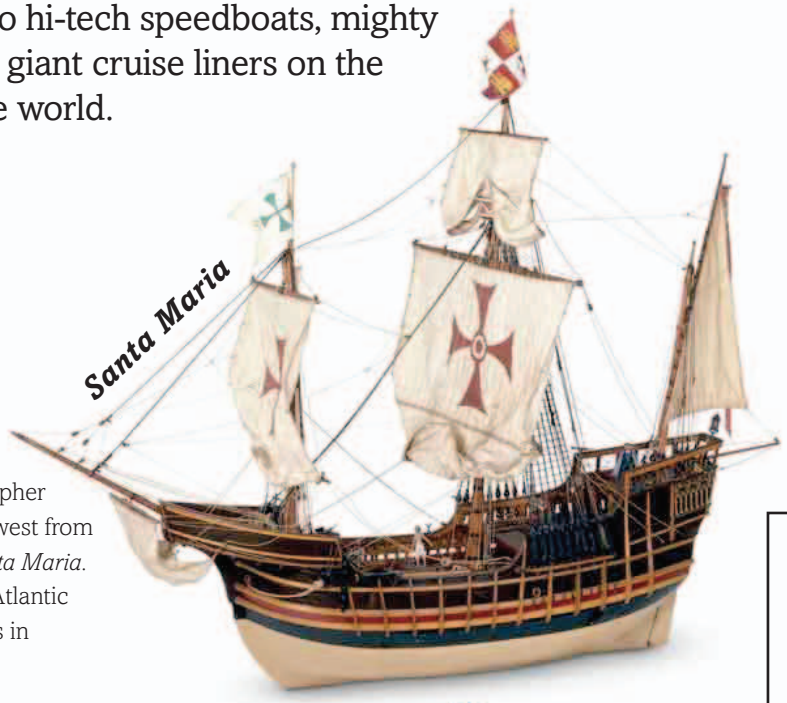
2015

First passenger-carrying test run of Japan's new maglev train system. Trains reach speeds of 373 mph (600 km/h).



Across the water

Humans have been traveling by water for so long that it is impossible to know exactly when the first boats were built. Some have changed little over the centuries, but today there are also hi-tech speedboats, mighty tankers, and giant cruise liners on the waters of the world.



1492

Explorer Christopher Columbus sails west from Spain in the *Santa Maria*. He crosses the Atlantic Ocean and lands in the Bahamas.

1500

1510

The English ship *Mary Rose* is one of the first to be built with gunports, holes for cannons to fire through.

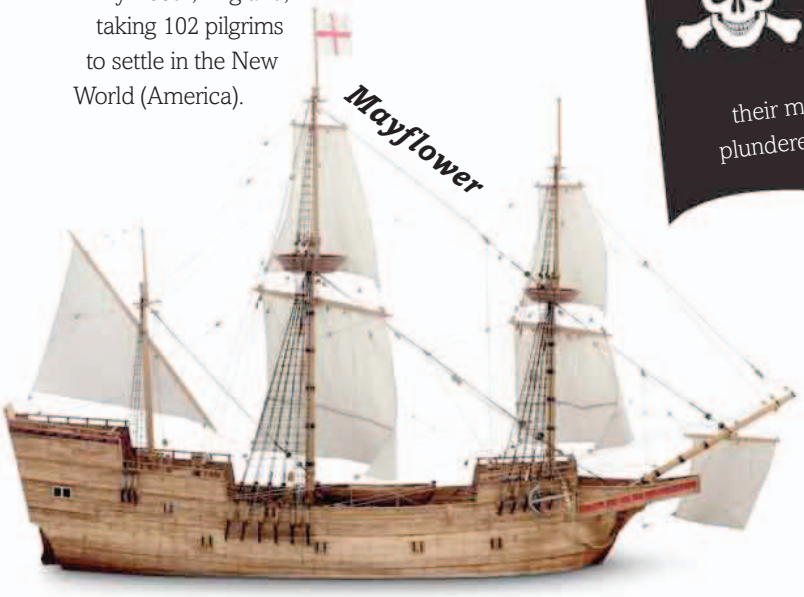
1519

Portuguese navigator Ferdinand Magellan sets out with a fleet of five ships. Just one would make it back in 1522, having completed the first voyage around the world.

1600

1620

The *Mayflower* leaves Plymouth, England, taking 102 pilgrims to settle in the New World (America).



1661

The first recorded yacht race takes place, between the English King Charles II and his brother James, on the Thames River in London.

1700

1716

In the early 1700s, the waters of the Caribbean were at their most dangerous, as pirates plundered Spanish treasure ships.

1768

Captain James Cook sets off from England to explore the South Pacific. His voyage takes three years and covers more than 30,000 miles (48,000 km).

1922
Water skiing was invented by 18-year-old Ralph Samuelson when he was pulled across Lake Pepin in Minnesota, USA, on two wooden skis.

2014 The CSCL Globe container ship goes into service. At 1,311 ft (400 m) long, it is the longest container ship in the world.

2012
Tûranor PlanetSolar, the largest solar-powered boat in the world, completes its trip around the globe.

1819
SS *Savannah* becomes the first steamship to cross the Atlantic Ocean.

1906
The *Dreadnought* is launched by the English king, George V. At the time, it was the most powerful battleship in the world.

1914
The Panama Canal, linking the Pacific Ocean with the Atlantic Ocean, opens. Ships no longer have to take the long and dangerous route around South America.

1977
NS *Arktika*, a nuclear-powered icebreaker, becomes the first surface ship to reach the North Pole.

1800 **1900** **2000**

1775
In the USA, the world's first combat submarine, the *Turtle*, is designed.

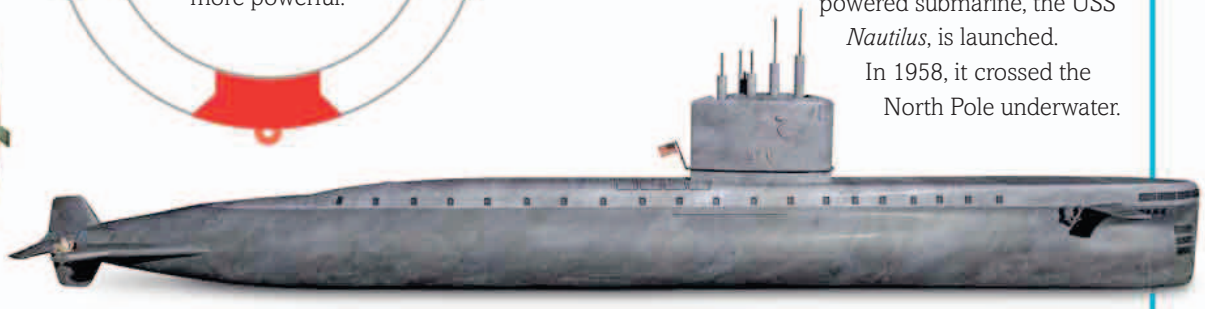
1912
On her maiden voyage, the RMS *Titanic* sinks after striking an iceberg in the North Atlantic.

2009
MS *Allure of the Seas*—the biggest passenger cruise liner ever built, launches.

1822
French scientist Augustin Fresnel designs a lens that makes the beam of a lighthouse five times more powerful.

1954
The world's first nuclear-powered submarine, the USS *Nautilus*, is launched. In 1958, it crossed the North Pole underwater.


Turtle


USS *Nautilus*

Up in the air

Powered flight took off in 1903 when American brothers Wilbur and Orville Wright attached an engine to a glider and traveled through air for 12 seconds. This short flight blazed the trail for supersonic jets, giant airliners, and even spacecraft.

1913 Russian Pyotr Nesterov becomes the first pilot to fly a loop-the-loop.

1785 Frenchman Jean-Pierre Blanchard and American John Jeffries fly across the English Channel in a balloon.

1783

In Paris, France, the Montgolfier brothers' hot-air balloon makes the world's first manned flight, lasting 25 minutes.

1900 The first rigid airship, the Zeppelin LZ1, makes its maiden voyage in Germany.

1903

The Wright brothers' first powered flying machine, the *Wright Flyer*, takes off in the USA.

1850

1900

1852

Frenchman Jules Henri Giffard's steam-powered airship makes its first flight, proving controlled flight is possible.

1891

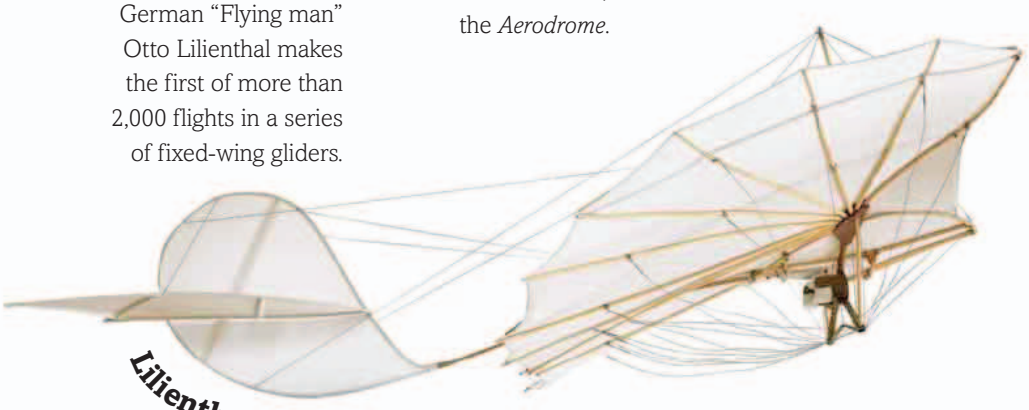
German "Flying man" Otto Lilienthal makes the first of more than 2,000 flights in a series of fixed-wing gliders.

1896

American inventor Samuel Pierpont Langley flies his steam-powered model aircraft, the *Aerodrome*.

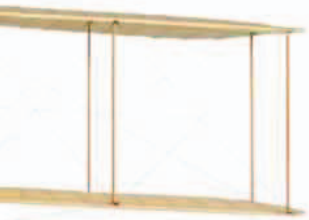
1907

The first flight of a rotary-wing aircraft, forerunner of the helicopter, is piloted by French engineer Paul Cornu.



Lilienthal's Normal Apparatus

1930 A nurse by profession, Ellen Church becomes the first flight attendant.



1969

In the UK, the Hawker Siddeley Harrier becomes the first vertical-take-off-and-landing (VTOL) military jet in service.

1938

The American Boeing 307 Stratoliner, the first airliner with a pressurized cabin, helps make flying a pleasant experience for passengers.

1969

The US Apollo 11 spacecraft takes off for the moon. Two of its astronauts become the first humans to walk on the lunar surface.

1981

Space Shuttle *Columbia* lifts off from Cape Canaveral, Florida, for its first space mission. The Space Shuttle program continues until 2011.

1950

2000

1952

In the UK, the first commercial jet airliner, the de Havilland Comet, enters service.

1961

Russian cosmonaut Yuri Gagarin becomes the first man in space. He orbits the Earth for 108 minutes onboard his Vostok 1 spacecraft.

1927

American Charles Lindbergh makes the first nonstop flight across North Atlantic in his Ryan NYP *Spirit of St Louis*, a distance of more than 3,600 miles (5,800 km).

1976

The UK/French supersonic airliner the Concorde enters passenger service.

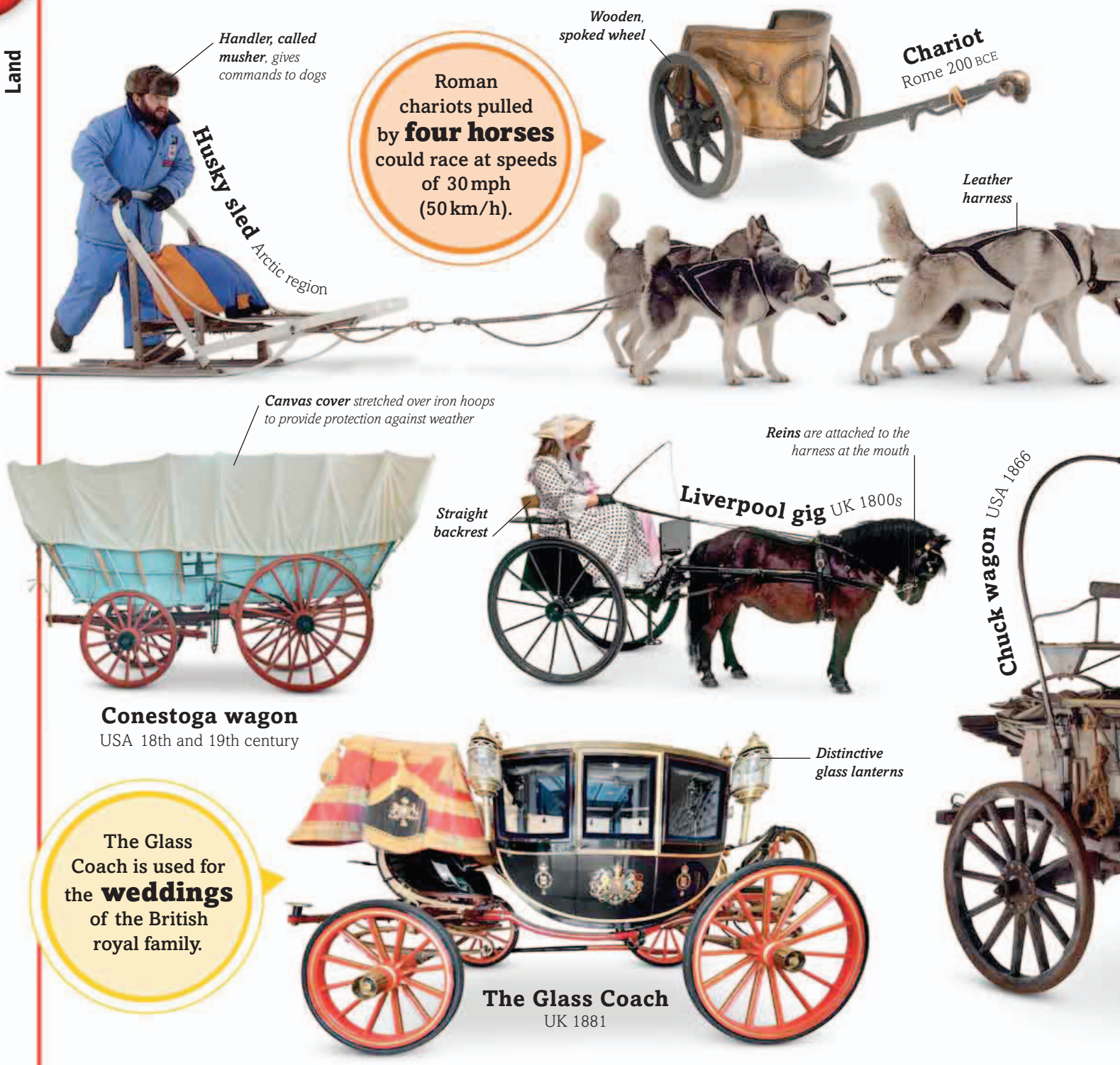
2014

After a 10-year journey, the European Space Agency spacecraft *Rosetta* reaches a comet and lands a probe on its surface.

1949 A B-50 Superfortress makes the first nonstop flight around the world. It is refueled in midair four times!

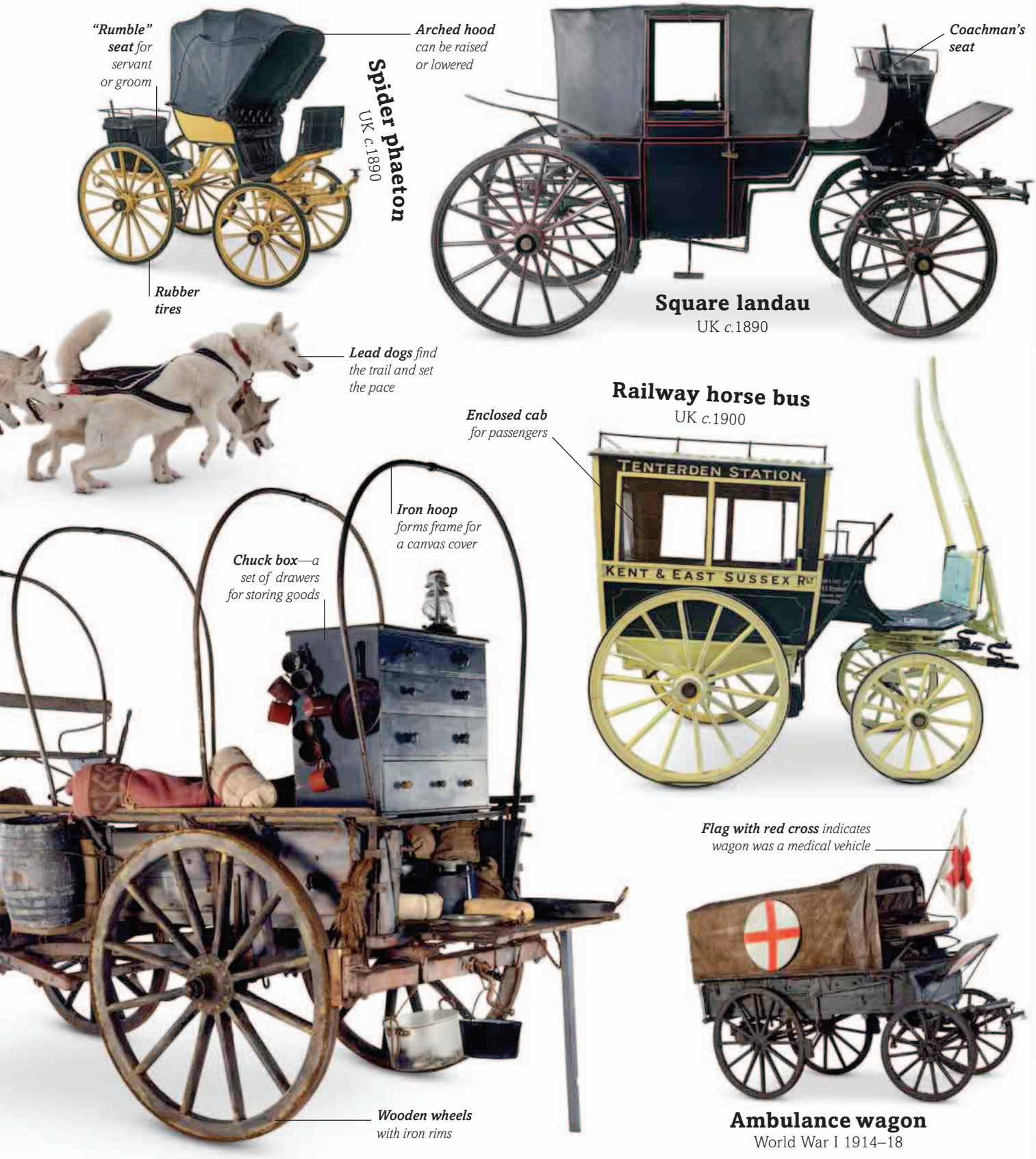
LAND

Animal power



For thousands of years, people have harnessed the power of large animals to transport them and their goods. Oxen, dogs, horses, mules, and reindeer have all been used to pull sleds or haul wagons and, in some parts of the world, still do.

As early as 3000 BCE, animals were used to pull the first chariots into battle in the Middle East and Asia. Later, the Romans turned **chariot** racing into a sport, using lightweight designs in which the driver rode from a small platform over the wheel axle. Wagons got bigger when pioneers set



Spider phaeton
UK *c.*1890

Square landau
UK *c.*1890

Railway horse bus
UK *c.*1900

Ambulance wagon
World War I 1914–18

off across North America in the 18th and 19th centuries. The four-wheeled, covered **Conestoga wagon** could carry five tons of food, tools, and belongings, and was usually pulled by oxen. Not long after, fully working kitchens on wheels, called **chuck wagons**, could be seen following cowboys as they herded cattle across the country. In the towns, small, lightweight carriages such as the **Liverpool gig** or the **Spider phaeton** carried up to two people on short journeys, while bigger carriages, such as the **Square landau** could transport four people in greater comfort.

CAMEL CARAVAN Out of the way, there's a convoy coming through! It's made up of camels carrying salt—Ethiopia's white gold, mined from the Danakil Depression. Highly prized, both to flavor food and preserve it, salt is levered out of the giant salt flats at Danakil in slabs. These slabs are then cut into blocks and lashed onto the backs of the camels, the ultimate desert pack animal.

Caravans (convoys) of pack animals—from camels, horses, and mules, to yaks, llamas, and even elephants—have been used throughout history to transport food, materials, and goods for trade. Camels are famed for their ability to withstand heat and a lack of water, making them perfect for cargo-carrying trips across hot deserts. This route across Ethiopia, from Danakil to the trading center of Mekele, involves a 60-mile (100-km) trek across one of the hottest places on Earth, with temperatures soaring past 122°F (50°C). Salt caravans have crossed the Sahara for more than 2,000 years. In the past, thousands of animals made up the camel trains, but today 20 to 30 are more common.

Bicycle

Bicycles are a fun and efficient way of getting around. A cyclist can travel around four to five times faster than a walker, using the same amount of energy. Although designs vary, most bicycles share common key parts. A chain, powered by a chainwheel and driven by pedals and cranks, transmits power to the rear wheel, which turns and drives the bicycle forward.

Saddle › The bicycle's seat can be solid or padded for comfort. It is attached to a seat post, which slides into the frame's seat tube.

Seat post

Rear brake cable

Seat tube

Rear brake

Wheel and tire › These support the weight of the bicycle and the rider. Different tires have different patterns on their outer surface known as tread. This bicycle has smooth tread tires for road racing. An off-road bicycle will have chunkier tread to provide better grip.

Gear cable

Rear derailleur › The derailleur gear moves the chain to different gear cogs.

Spokes › Thin and strong, spokes connect the wheel's rim to its center, or hub. They allow wheels to be built that are strong but light in weight, and they let air through when the wheel faces the wind.

Chainwheel

Chain

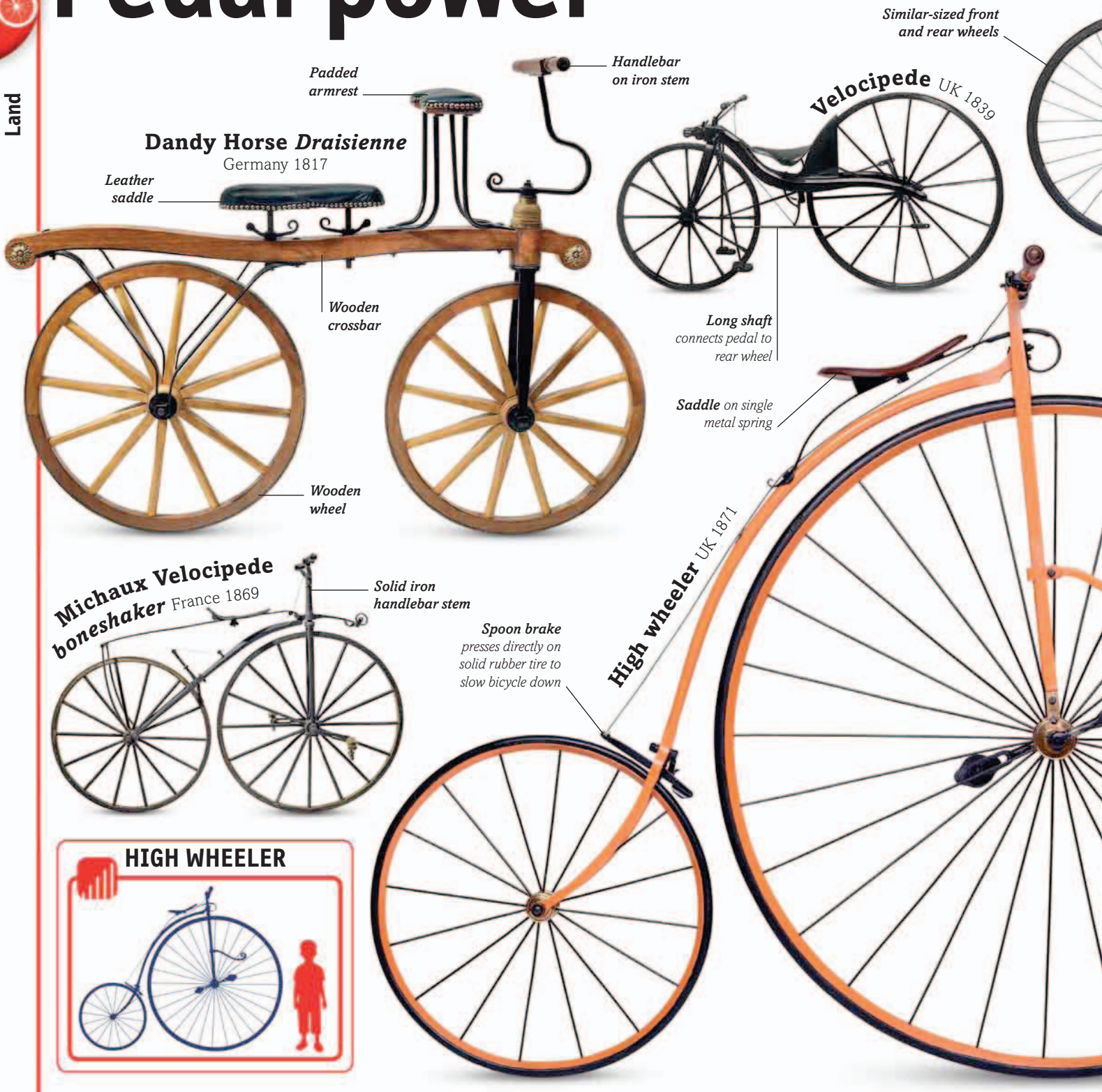
Bottom bracket

Handlebars › These act as a lever for the rider to grip and turn the front wheel when steering. They also hold the gear controls, bicycle computers, and brake levers. This racing bicycle has dropped handlebars for a low, tucked-in riding position.

Frame › This is the skeleton of the bicycle, to which all the other parts are attached. The frame is usually formed out of hollow tubes of steel for cheaper bikes, or aluminum combined with other metals (alloy), titanium, or carbon fiber for higher performance models.

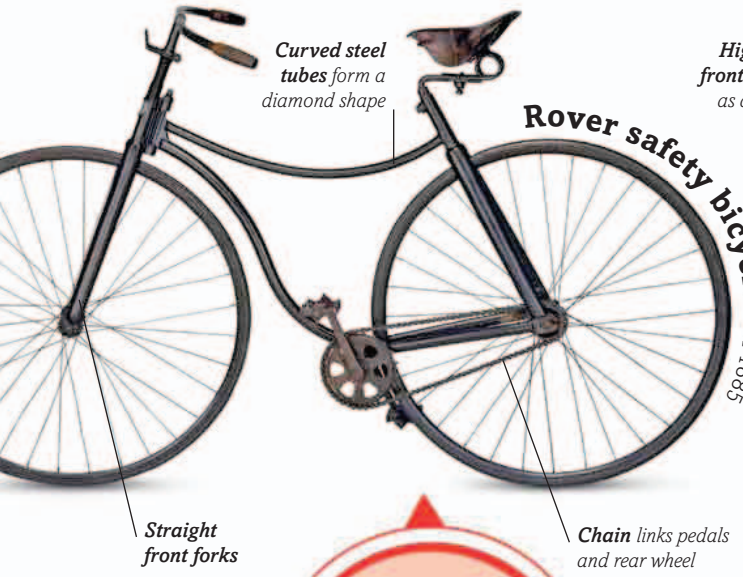
Crank › The crank is a shaft connecting the pedal to the toothed chainwheel through a series of arms called a spider. The spider and chainwheels turn on the bottom bracket axle.

Pedal power



Considering the wheel has been around for more than 5,000 years, it is amazing to think that it was only 200 years ago people finally got the idea to place two wheels on a frame and create pedal-powered personal transportation.

The German Baron Karl Von Drais invented the **Dandy Horse** in 1817, which had a saddle and handlebars but was powered by a rider paddling his feet along the ground. It led to other human-powered machines, including the **Michaux Velocipede**, which had pedals fitted directly



Curved steel tubes *form a diamond shape*

Rover safety bicycle UK 1885

Straight front forks

Chain *links pedals and rear wheel*

High wheeler front wheel *acts as a rear wheel*

Singer tricycle UK 1888

In **1885**, the Rover bicycle won a **100 mile** (160 km) race in the UK in 7 hours, 5 minutes.

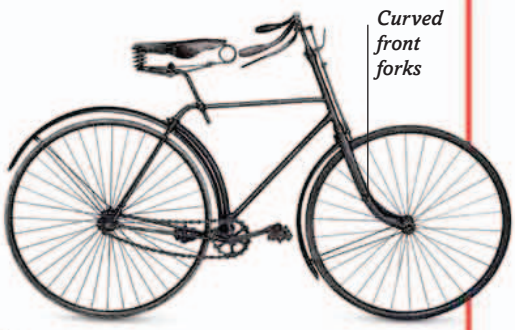
Large front wheel *up to 5 ft (1.5 m) in diameter*

Solid rubber tire, *replaced by pneumatic (air-filled) tires from 1888*

Swift safety bicycle UK 1887

Simple mudguard *covered the small rear wheel*

Facile dwarf safety bicycle
UK 1888



Curved front forks

Singer safety UK 1888

In **1884**, Thomas Stevens crossed the **USA** on a **high wheeler**.

Saddle *made of 131 ft (40 m) of woven cord weighs 3½ oz (100 g)*

Dursley Pedersen bicycle UK 1898–99

to the front wheel. The experience of its iron "tires" on cobbled streets earned it the nickname *boneshaker*. **High wheelers**, or Penny Farthings, in the UK, France, and the USA had no chains or gears, but had bigger front wheels to boost speed. It perched the rider high above the ground, resulting in many falls. Alternatives were sought, including pairing two high wheeler front wheels to form the rear wheels of the **Singer tricycle**, and using a chain-driven rear wheel, as in the **Rover safety bicycle**. This design ushered in the modern bicycle with wheels of similar size.

Speed wheels

Isaac Force Germany 2005

Dedacciai Strada Assoluto Italy 2011

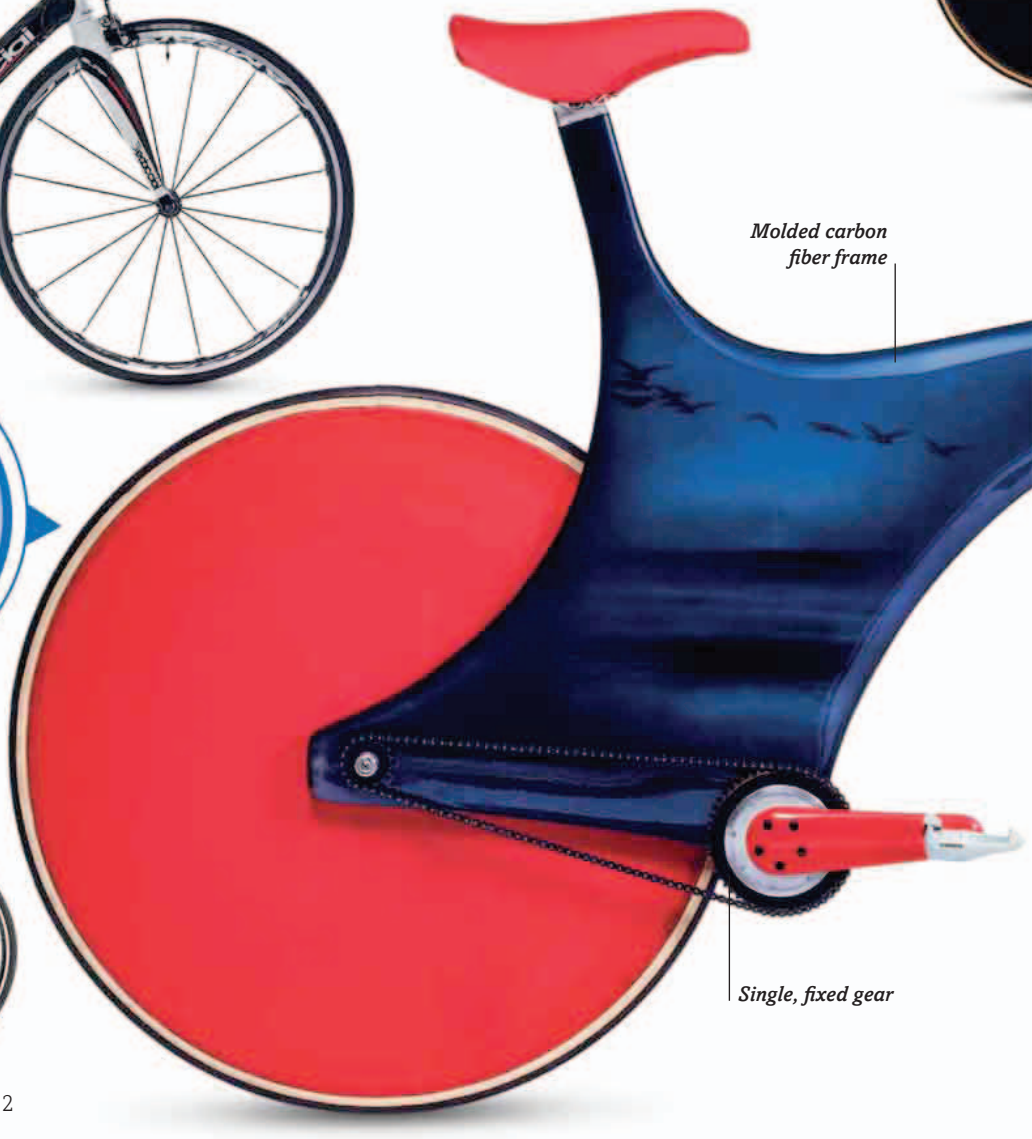
Rear wheel with spokes and carbon fiber rim

Dropped handlebars

Tires inflated with helium gas to save ⅜–⁹⁄₁₆oz (10–15g) per tire

Molded carbon fiber frame

This revolutionary track bicycle weighed just **20lb (9kg)**.



Women's bicycles often have narrower handlebars

Marin Ravenna A6WFG USA 2012

Single, fixed gear

If you have a need for speed, then a racing bicycle is for you. Designed for fast riding on smooth surfaces, racing bicycles are light in weight with a high seat and low, dropped handlebars.

Not all racing bicycles are used for racing. Many are used by cyclists to commute rapidly to work or for a workout. Frames are designed for both men and women; the **Ravenna A6WFG** is a women's racing bicycle designed for endurance riding. Competition racing bikes are designed with super-

lightweight frames of aluminum or titanium alloys, or carbon fiber. The **Assoluto's** carbon fiber frame weighs just 2 lb 6 oz (1.1 kg), a little more than a baseball bat. Solid disk rear wheels are used on track racers, in time trials, and on triathlete's bikes such as the **Cervelo P5**, because they are more aerodynamic (cut through air more easily) than wheels with spokes. Solid-bodied track racers, such as the **Windcheetah Carbon Cantilever**, appeared in the 1980s with a solid carbon fiber body. They were tested in wind tunnels to ensure they were as aerodynamic as possible.

SPRINT FINISH You can feel the pain just watching these sprinters pump the pedals at the end of another grueling stage of the world's most famous bike race, the Tour de France. This stage—the tenth of the 2011 Tour—started 98 miles (158 km) back. In a photo finish, André Greipel of Germany (right) crossed the line a fraction ahead of Mark Cavendish of the UK (left). Both are given the time of 3 hours, 31 minutes, and 21 seconds.

The Tour de France takes place over three weeks every summer. It covers more than 2,175 miles (3,500 km), broken up into 21 stages. Each year, the route across France changes, sometimes entering other European countries, but it always challenges riders over all sorts of terrain, with stages on the flat, in the hills, and in the mountains. Around 20 teams take part, each with nine riders. The cyclists' times for each day are added together and the rider with the overall lowest time gets to wear the prized *maillot jaune* (yellow jersey). But there are also prizes for the fastest sprinter (green jersey), the fastest climber (red polka dot jersey), the fastest rider under 25 (white jersey), and for the fastest team.

Bike business

Police mountain bicycle
Germany 2000s

There are more than **1,200 parts** in a Brompton Folding Bicycle.

Brompton Folding Bicycle UK 1981–83

Cycling may be lots of fun, but many people ride their bicycles to and from work, or use them in order to do their jobs. Bicycles offer a cheap, quick, and convenient way to get around, and to transport people and deliver goods.

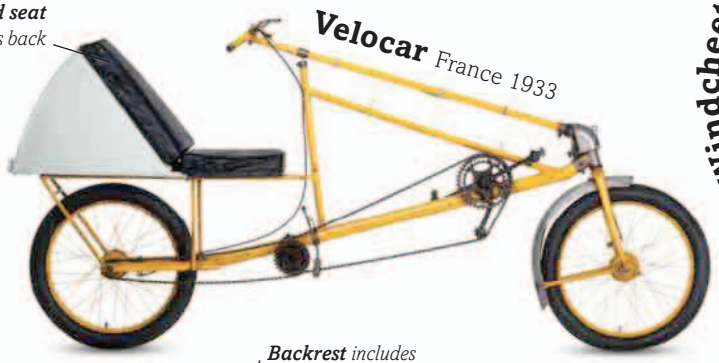
In both crowded towns and cities, and isolated countryside areas, **police mountain bicycles** allow officers to get to a crime scene quickly. **Response bicycles**, with their pannier bags filled with lifesaving medical equipment, can get through traffic or crowds to reach a patient where

larger vehicles cannot go. The **BSA Airborne** was used by British troops during World War II—its frame folded in half when two butterfly screws were loosened. Folding bicycles, such as the **Brompton Folding Bicycle**, continue to be used by thousands of commuters. Delivery bicycles are equipped with baskets or carriers to carry cargo. The **DHL Parcycle** fits a giant container onto a bike to carry packages. Bicycles can also be modified, and their frames attached to carts or carriages, such as the **ice cream cart** and the pedal-powered **Penang Trishaw** taxi.

Fun on wheels

Unicycle France 1800s

Padded seat *supports back*



Velocar France 1933

Windcheetah SL Mark VI *Speedy* UK 1981

Backrest *includes lockable trunk and rear lights*

Kingcycle UK 1990s

Riders experience "rubber legs" when they try a new style of bike and use new muscles.

Dropped handlebars *with brakes for the rider at the back*

Santana Triplet USA 2000s

If you think all bicycles feature just one rider sitting upright, supported by two wheels, think again! Many variations on the bicycle's basic design have been attempted for greater speed, more comfort, or just for fun.

A **unicycle** has a single wheel, turned by pedals, and demands great balance from the rider to stay on. Three-wheelers are easier to ride, and some, such as the **Pashley Tri.1**, even offer a platform to carry large loads. Tandem bicycles, such as the **Dawes Galaxy Twin**, have two riders pedaling,

but only the front rider steers. The **Santana Triplet** has seats for three riders, with a long chain linking each rider's chainwheel to ensure smooth pedaling. In recumbent bicycles, riders sit or lie down with their legs out in front; the bicycle is low and can slip through air at high speed.

The **Windcheetah *Speedy*** was cycled the length of the UK in just 41 hours, 4 minutes, 22 seconds. Some recumbents fit a body shell around the rider to let air flow past more smoothly. In 1990, the **Kingcycle Bean** set a world speed record of 47 mph (76 km/h) over one hour.

Extreme cycling

Trek 8900 Pro USA 1990

Suspension *allows front forks to telescope down into lower tubes when hitting bumps*

Frame *made of carbon fiber tubes fitted to aluminum joints*

Gear changer *on the handlebar helps select between the bicycle's 15 gears*

Single gear cog *on rear wheel*

Specialized Stumpjumper
USA 1981

Raleigh Kool Max UK 2000s

2ft-6in- (6.4-cm-) wide tire *for great grip in sand, dirt, and mud*

Fat Chance Yo-Eddy USA 1991

Some mountain bicycles have up to **30 gears** to speed over different conditions.

Trek 6000 USA 1991

Toe straps *secure rider's feet on pedals*

Shock absorber *cushions bumps*

Hydraulic *(fluid-operated) disk brakes*

Stumpjumper FSR Pro USA 2004

While ordinary bicycles can be ridden off-road, their smooth tires and slender frames are not suitable for rough stuff. When bikers in the USA began redesigning bicycles for better off-road performances in the 1970s, mountain biking was born!

The first mountain bicycle made on a large scale was the **Specialized Stumpjumper**. Only 500 were initially produced, but they started a revolution. Soon, many manufacturers came up with their own designs. The **Trek 6000** had a lightweight, all-aluminum frame, while the **Trek**

Marin Nail Trail
USA 2014

MBM Instinct BMX stunt bicycle Italy 2000s

Haro Freestyler BMX racing bike USA 2012

8900 Pro's frame was made of carbon fiber to keep its weight down. Many mountain bikes are fitted with suspension systems. Hardtail bicycles (with rigid frames), such as the **Marin Nail Trail**, have front forks that lessen the impact of bumps and landings. In contrast, full-suspension bicycles, such as the **Stumpjumper FSR Pro**, have shock absorbers for both wheels. BMX bikes are strong, small-wheeled bicycles, some of which are raced over dirt tracks. Freestyle (stunt riding) BMX bikes such as the **MBM Instinct**, are built for doing tricks and out-of-the-saddle moves.

MOUNTAIN BIKE MADNESS

MTB freerider Louis Reboul launches his mountain bike off a giant 52-ft- (16-m-) high ramp during the Red Bull Rampage 2014. He twists the bike and his riding position in midair to pull off a perfectly judged landing. One mistake and the result could be disastrous, with a huge drop onto the hard, unforgiving sandstone below.

Mountain bike (MTB) freeriding involves riders pulling moves and tricks as they take on a challenging run, full of dramatic natural features and, sometimes, man-made obstacles such as large ramps. Competitors ride bikes with full suspension on both wheels to allow for heavy impacts on landing, and their runs are judged for speed, control, and the execution and complexity of their tricks. These can involve full 360° spins, backflips, and no-hands riding. Held on the edge of Zion National Park in Utah, the Red Bull Rampage is an annual invite-only tournament for some of the hottest freeriders in the world. Each gets to pick their own route along the almost-vertical drops of ridges and cliffs.

Motorcycle

Bikes were first fitted with engines in the 19th century and have never looked back! Today, millions enjoy the fast, convenient travel and the freedom of the open road or trail that motorcycles provide. This **Yamaha XJR 1300** is called a "naked" bike, because its engine is not hidden behind body panels. With a top speed of 130 mph (210 km/h), it is faster than many cars.

Chassis › The frame to which other parts of the motorcycle are attached, the chassis helps keep the wheels in line for good handling. It is usually made of steel or a combination of metals (alloy).

Rear seat › Big motorcycles have a seat long enough for a passenger, who can grip the handle behind the seat.

Indicator light

Shock absorber › A coil-spring and oil-filled cylinder cushion the bike and rider over bumps in the road.

Rear wheel › This is driven by power from the engine through a shaft or belt, or on this motorcycle, a metal chain similar to a bicycle chain.

Exhaust pipe › The exhaust pipe channels waste gases from the engine out behind the bike.

Side mirrors › Mounted on the handlebars, these allow the rider to see what's going on behind the bike.

Throttle › Controlled by twisting the right handlebar, the throttle controls the flow of gas and air mixture into the cylinders in the engine. More air means more power and a higher speed.

Windshield

Fuel tank › The tank holds the gas and pumps it to the engine.

Headlight › Powered by the motorcycle's alternator, this lights up the road ahead.

Front wheel › Fitted with an air-filled tire, this wheel is steered by the handlebars.

Front forks

Brake disk

Engine › Fueled by gasoline, the engine generates power, which is transmitted to the rear wheel. This engine generates around 107 horsepower, as much as a hatchback car.

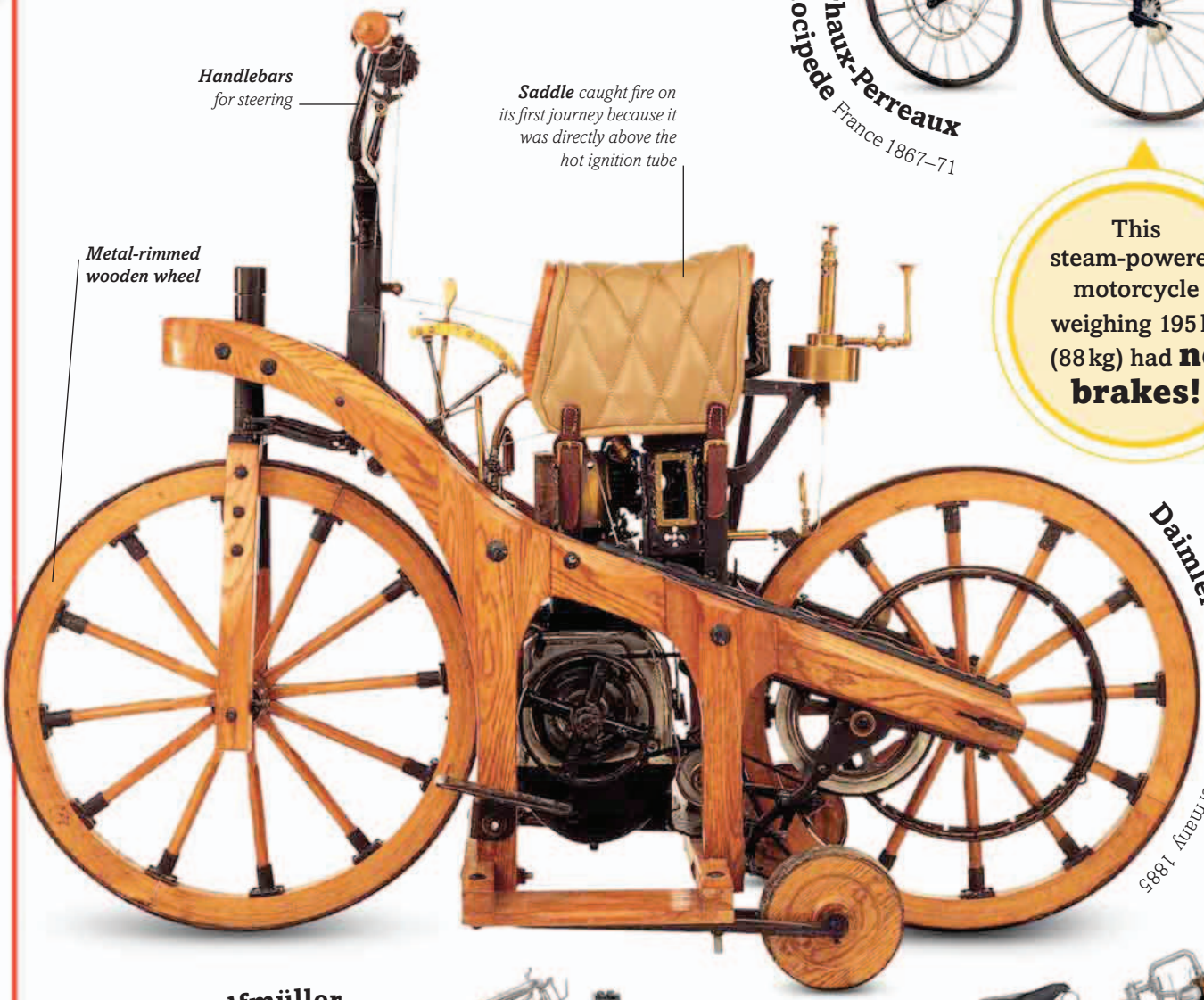
Revving up

Michaux-Perreaux velocipede France 1867–71

Handlebars for steering

Saddle *caught fire on its first journey because it was directly above the hot ignition tube*

Metal-rimmed wooden wheel



This steam-powered motorcycle weighing 195 lb (88 kg) had **no brakes!**

Daimler Reitwagen Germany 1885

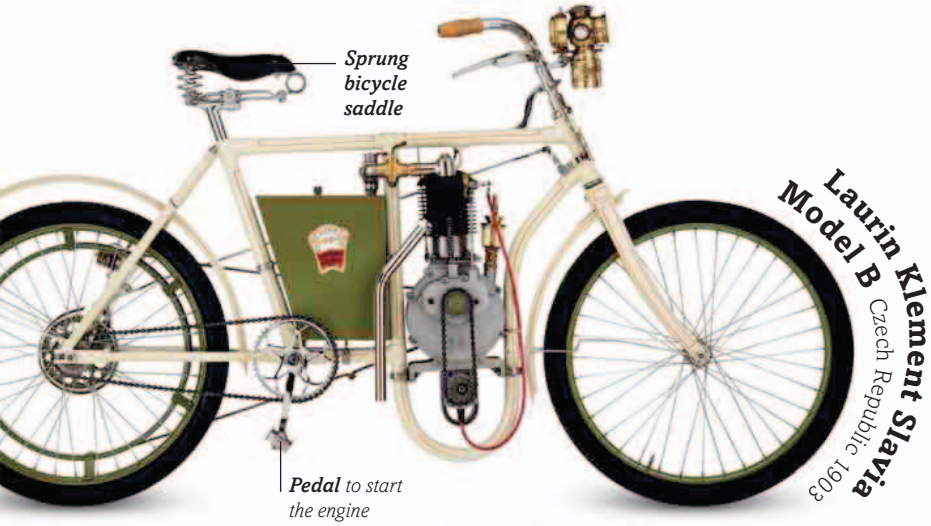
Hildebrand & Wolfmüller Motorrad Germany 1894

Mudguard *was also the motorcycle's water tank*

Cyklon Germany 1901

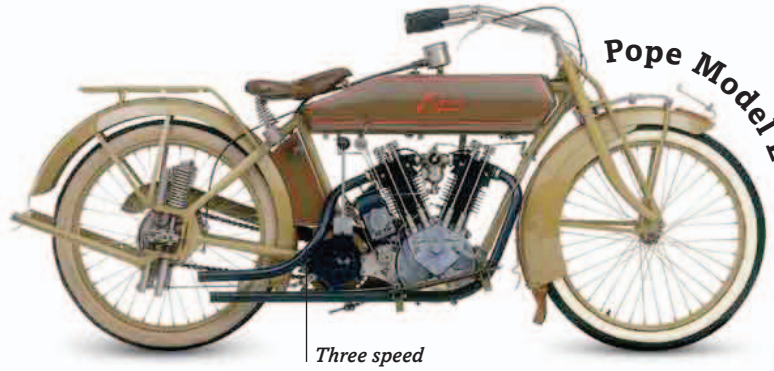
The first powered motorcycles used a small steam engine to drive the rear wheel, but motorcycles made a great leap forward once internal combustion engines were built small enough to attach to a bicycle-styled frame.

With its 0.5 horsepower engine, the **Daimler Reitwagen** is considered to be the first "real" motorcycle, even though it was crafted out of wood. It proved to be an uncomfortable ride due to its wooden wheels and lack of suspension. The faster **Motorrad** and the first widely made

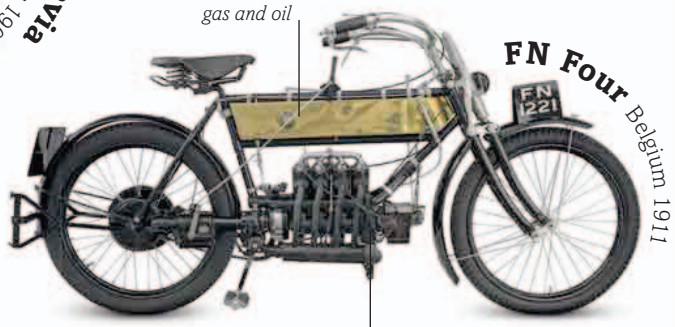


Laurin Klement Slavia Model B Czech Republic 1903

Indian Single USA 1904

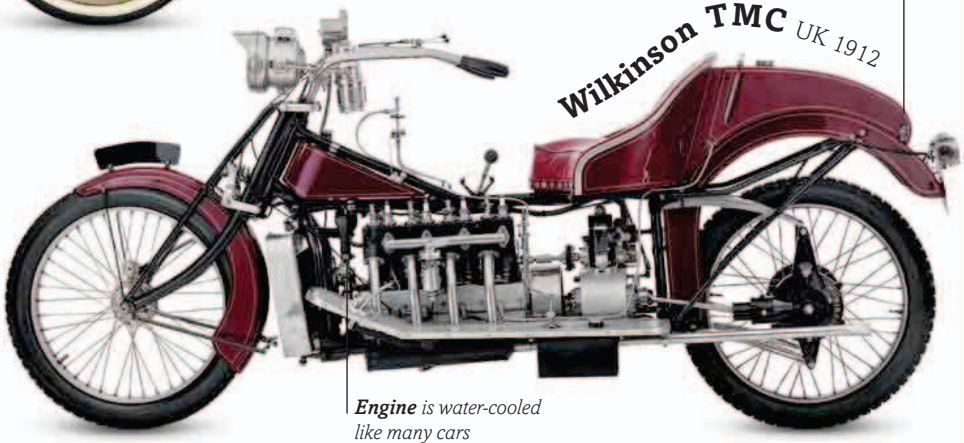


Pope Model L USA 1911

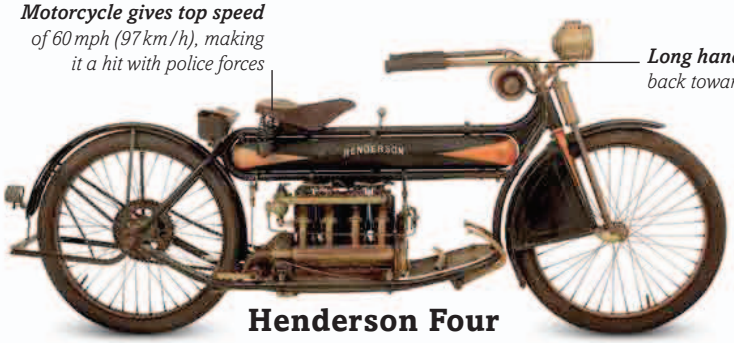


FN Four Belgium 1911

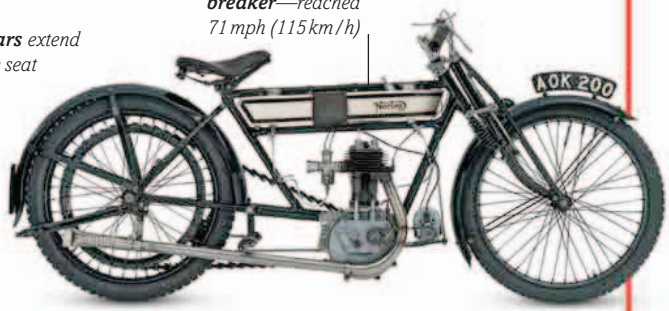
Carl Clancy rode **17,895 miles** (28,800 km) around the world on a Henderson Four in 1912.



Wilkinson TMC UK 1912



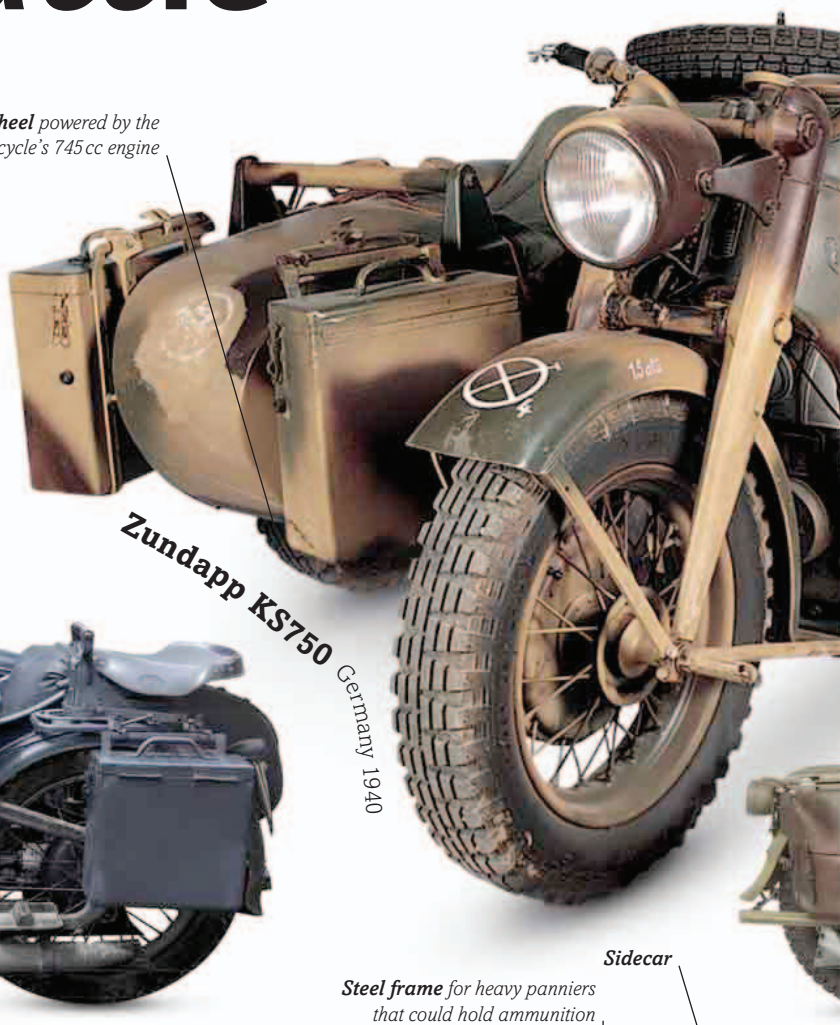
Henderson Four
USA 1912

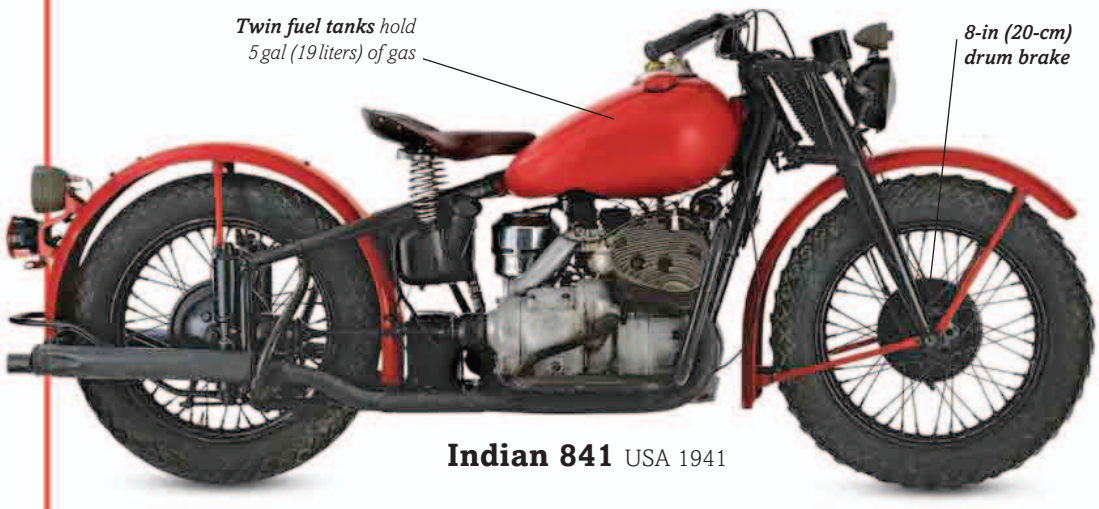


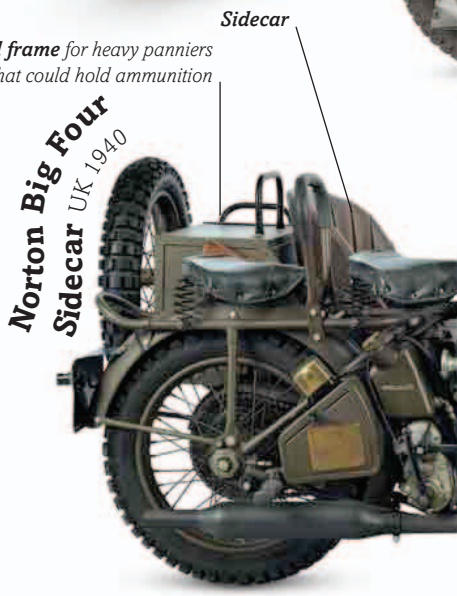
Norton *Old Miracle* UK 1912

motorcycle, with around 2,000 built. Some early motorcycles had their engines mounted in strange places. The **Cyklon's** engine sat in front of the rider; it drove the front wheel around. The **Indian Single's** engine was so low, riding over a bump could knock it. Over time, engines were built with more than one cylinder. The **Pope Model L** had two cylinders and cost as much as a Ford Model T car. The **FN Four** was one of the first motorcycles with four cylinders. The four-cylinder **Wilkinson TMC** was designed for long-distance touring with a padded leather seat, but it had no front brake.

Bikes in battle







As motorcycles became faster, sturdier, and more reliable, they were adopted by armed forces in their thousands. World War II saw heavy motorcycle use, as scouts, in convoys, and as couriers, transporting messages and people.

Many World War II motorcycles were adapted civilian models. More than 70,000 **Harley-Davidson WLAs** were made for the American forces, while 126,000 **BSA M20s** were built by the UK and its allies—making it the most produced motorcycle of the war. A prewar Harley-Davidson

A **Welbike** could be put together in just **11 seconds**.

built in Japan, the **Rikuo Type 97** served Japanese forces during wartime. Its sidecar was engine-powered, improving travel over rough ground, a feature also found in the sidecar of the **Norton Big Four**, used as a scout by British soldiers. The 930-lb (420-kg) **Zundapp KS750** was one of the biggest World War II sidecars. In contrast, the 71-lb (32-kg) **Welbike** could be folded inside a cannister, dropped from a plane, and parachuted to the ground. Another lightweight, the ***Flying Flea*** was used to carry messages when radio contact was impossible.

Scooting around

Cushman Auto-glide
USA 1938

Lambretta LD150 Italy 1957

Vespa Rally 250
Italy 1976

Honda Super Cub C100
Japan 1958

More than **60 million** Super Cubs have been built—the most produced motor vehicle ever.

Scooters are small motorcycles with a step-through design and the driver's seat above an enclosed engine. The term *mopeds* once meant motorized bikes that had to be pedaled to start, but now it applies to small scooters with 50 cc or lesser power engines.

The **Autoped** was one of the first scooters; its engine drove the front wheel using gears. The **VéloSoleX 45**, an early moped, had an engine that powered a ceramic roller that gripped the top of the front wheel to turn it. Lightweight and fuel-efficient, scooters and mopeds such as the

Honda Super Cub proved to be a cheap form of transportation in the postwar years. A craze for stylishly designed Italian scooters in the 1950s and 1960s led to the popular **Lambretta LD150** with its large windshield, passenger seat, and top speed of 50mph (80km/h). Scooters and mopeds are still in demand. The **Yamaha Jog** and the **PGO PMX**, powered by small 50 cc engines, are aimed at young riders. Future scooters may be enclosed with a roof, such as the **BMW C1 200** concept, or be powered by electric motors, like the **BMW C Evolution**.

Three-wheelers

Not all motorcycles have two wheels. Ever since bikes were first developed, engineers have experimented with three-wheeled machines, which are easier to learn to ride, have more space for engines or loads, and come with an extra tire for better grip.

Early three-wheelers were pedal-powered tricycles fitted with an engine. The **Ariel Tricycle** used the space between the rear wheels for the engine. Some manufacturers preferred to power a single rear wheel, so they placed a pair of wheels in the front. Both the **Rexette 5HP** and **Raleighette**

Honda Goldwing EML Trike
Japan/Netherlands 1994

Vandenbrink Carver One Netherlands 2007

Three-wheeled car-like body *tilts up to 45 degrees, with wheels staying on the road*

Short, plastic windshield *deflects air up and over rider's head*

Each Can-Am front wheel has its own **suspension** to ride out **bumps**.

Weighs 335 lb (152 kg), *a quarter of the Carver One*

Can-Am Spyder Trike
Canada 2011

Yamaha Tricity
Japan 2014

Twin six-spoked wheels *with 13.8 in (35 cm) diameter*

Tricar had rear-wheel drive and used the space above the front wheels to fit a passenger chair. The **Harley-Davidson Servi-Car GE** served police forces and breakdown mechanics from the 1930s to the 1970s. In contrast, the **Can-Am Spyder** is built for fun and has as much power as a small hatchback car. Advances in technology have brought in new three-wheelers that can tilt their bodies as they turn. The **Vandenbrink** is like a three-wheeled car, with a fully enclosed cockpit and twin rear wheels, while the **Yamaha Tricity** resembles a motorcycle with twin wheels in front.

Road burners

License-plate holder

Low-lying exhaust pipe

Royal Enfield 500 Twin UK 1951

Seat with springs underneath

Front fender shows name of motorcycle

Harley-Davidson Electra Glide USA 1965

Honda CB550 Four Japan 1976

Rear tire with 18 in (45 cm) diameter, 3¾ in (9.4 cm) width

More than **3,000** police units across the **USA** use Harley-Davidsons.

Chrome front forks

Kawasaki H2C Japan 1975

KMZ Dnepr MT11 Russia 1985

BMW R60/6 Germany 1976

Various types of motorcycles have been designed for road use, from standards to cruisers. Most standards offer a relatively upright riding style and have smooth tires. Cruisers are bigger, with a reclining back and relaxed riding position for long rides.

Standard motorcycles are ideal for riding around town and for short journeys. Popular midsize engine bikes in the 1970s included the **BMW R60/6** and the **Honda CB550**, with a top speed of 102 mph (164 km/h) from its 500 cc engine. For long-distance riding, cruisers are more

Powerful headlight

Ducati M900 Monster Italy 1994

*Long exhaust **pipe** from engine cylinder*

*Large twin 12-ft-6-in-(32-cm-) diameter **brake disks** for high braking power*

Harley-Davidson FLSTF Fat Boy USA 1999

A **Fat Boy** starred in the **Terminator 2** movie.

BMW R1200 RT Germany 2005

***Engine** gives top speed of 135 mph (217 km/h)*

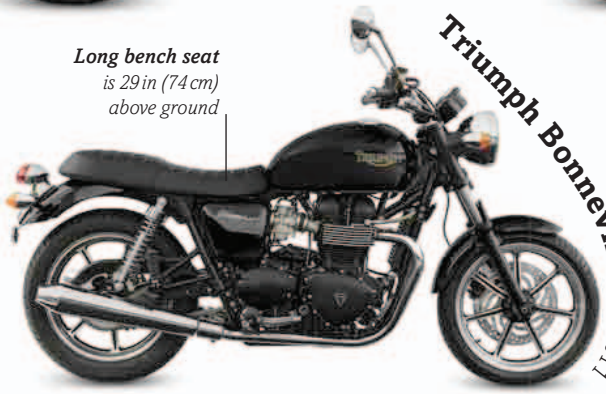
Yamaha FZS1000 Fazer Japan 2002

5.5 gal (21 liter) fuel tank

Instrument panel on top of fuel tank

Triumph Thunderbird UK 2010

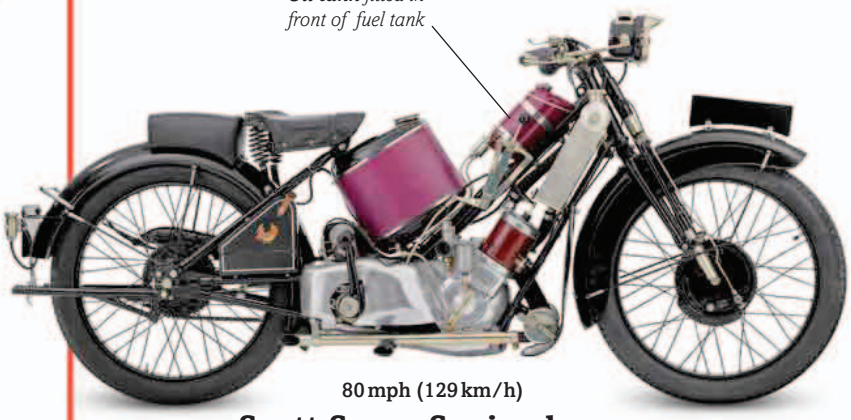
Long bench seat is 29 in (74 cm) above ground



Triumph Bonneville UK 2011

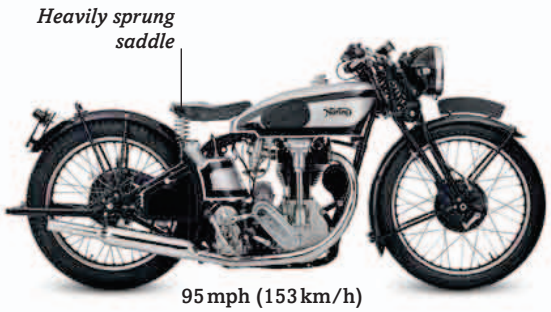
popular. The **Electra Glide** was the first big Harley-Davidson motorcycle to have an electric engine starter. The **Thunderbird**, manufactured in UK, was Triumph's first belt-driven motorcycle since the 1920s. Muscle bikes have powerful engines and are shaped to look as modern as possible. The **Ducati M900** stands out with its large, sculpted fuel tank and unusual triangular frame. Other road motorcycles have picked up design elements from classic machines, such as the **Harley-Davidson Fat Boy** and the **Triumph Bonneville**.

Burning rubber



80 mph (129 km/h)

Scott Super Squirrel UK 1927



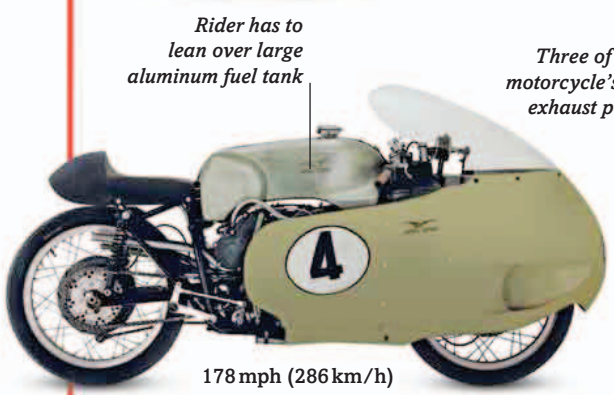
95 mph (153 km/h)

Norton International 30 UK 1936

130 mph (209 km/h)

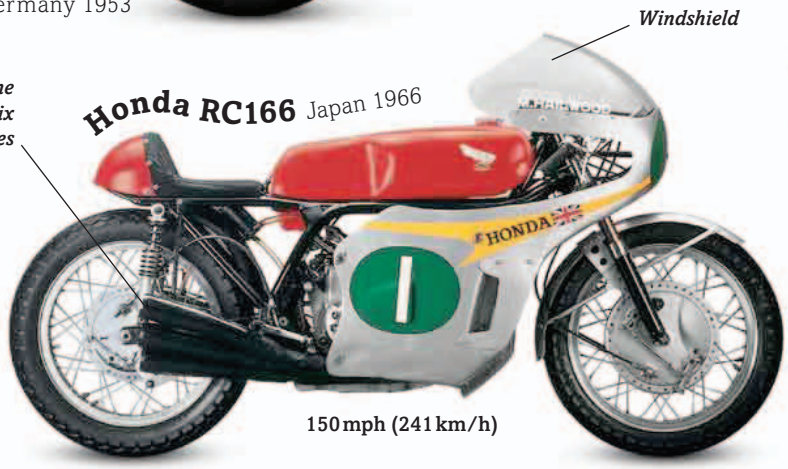
NSU Rennmax Germany 1953

The RC166's engine could turn at **20,000 rpm**, which is 333 turns every second!



178 mph (286 km/h)

Moto Guzzi V8 Italy 1957

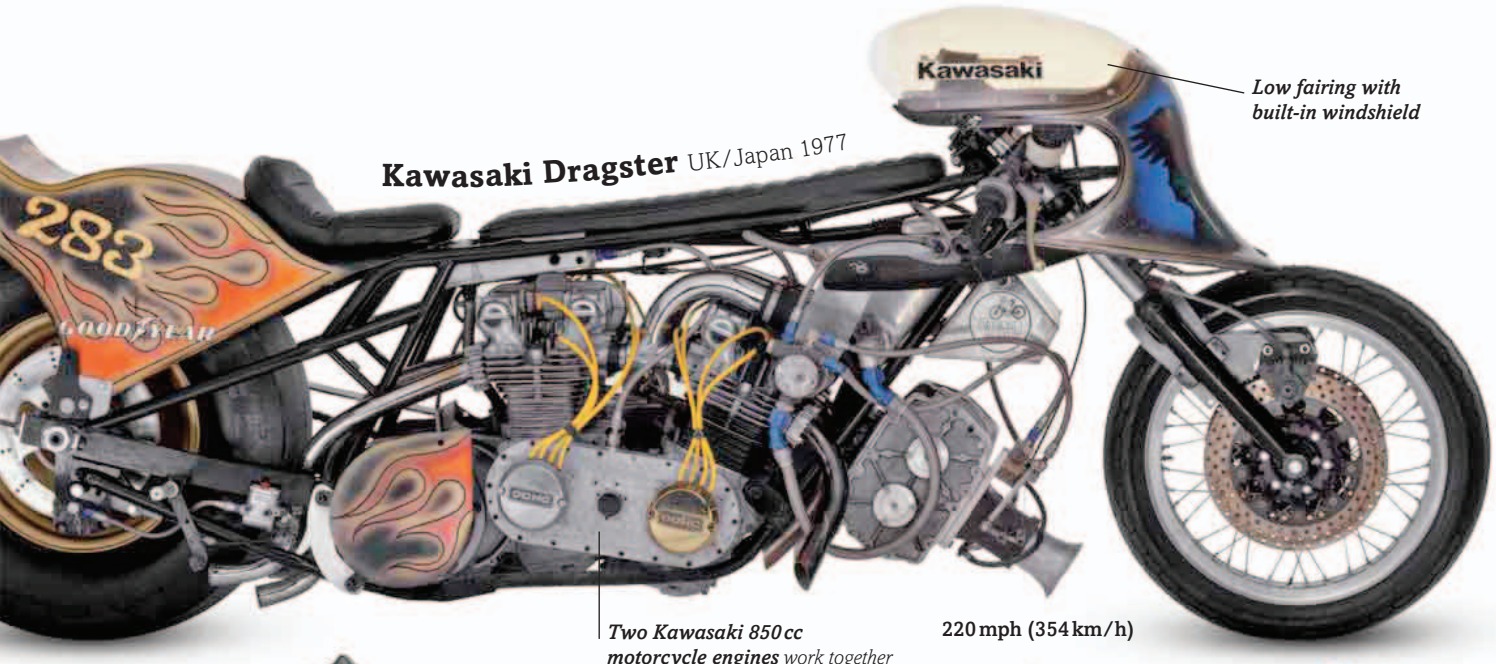


Honda RC166 Japan 1966

150 mph (241 km/h)

Racing motorcycles are built and tuned for ultimate performance, and maximum speed, acceleration, and braking power on the track. Sports bikes also boast high performance, but are used on roads. Some mimic the style and features of racers.

Early racing motorcycles, like the **Scott Super Squirrel** and the **Norton International 30**, competed in different kinds of races, from track races to time trials. In 1934, the Nortons finished first, second, third, and fourth in the famous Isle of Man TT (time trial). Track racers compete



Kawasaki Dragster UK/Japan 1977

Low fairing with built-in windshield

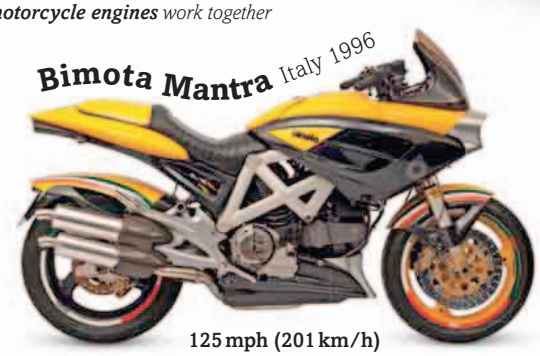
Two Kawasaki 850 cc motorcycle engines work together

220 mph (354 km/h)

Sculpted seat for low riding position

Suzuki RG500 Japan 1986

147 mph (237 km/h)



Bimota Mantra Italy 1996

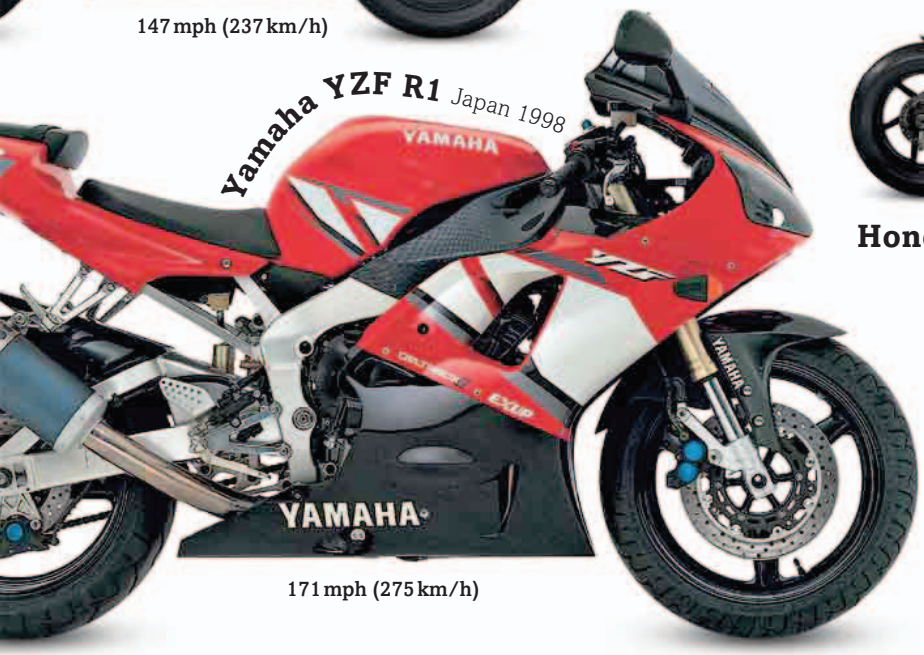
125 mph (201 km/h)

The Dragster could reach **149 mph** (240 km/h) in just **7.7 seconds**.

Wide, slick, treadless tire for racing on smooth tracks

200 mph (320 km/h)

Honda CBR1000RR Fireblade Japan 2009



Yamaha YZF R1 Japan 1998

171 mph (275 km/h)

Aprilia RSV4 Italy 2011

Single racing exhaust made of titanium metal

180 mph (290 km/h)

according to their type and engine size. The **Honda RC166** weighed 247 lb (112 kg) and had a 250 cc engine, yet it could race at speeds up to 150 mph (241 km/h). Modern racers, such as the **Aprilia RSV4**, are packed with electronic wizardry. An RSV4 rider can adjust the motorcycle's suspension, gearbox, and engine performance while riding. Manufacturers can produce street versions of their more successful racers. The **Suzuki RG500** was based on the racing RG500s, which had won four 500 cc Grand Prix World Championships in seven years.

JUMPS AND FLICKS Woooah! Pedro Moreno pulls a spectacular midair move during the 2013 freestyle competition in Zurich, Switzerland—the largest freesport event in Europe. Moreno is a professional freestyle motocross (FMX) rider. This is a sport in which motocross riders perform routines, throwing stunning shapes and pulling wicked tricks in the air as their bikes leap off giant ramps.

Freestylers use modified motocross racing motorcycles with a number of adjustments. These include shaving the foam saddle down to narrow it, replacing components with lighter variations, and rerouting cables to keep from getting boots tangled up in them as they perform their tricks and moves. These can be spectacular, such as full backflips by both bike and rider; "the cliffhanger," where the rider hooks his or her toes under the handlebars; and "the tsunami," where the rider performs a handstand over the handlebars while keeping the bike horizontal! Riders can also twist in the air, grab the saddle, and even let go of the bike completely, but they must nail a safe landing to get great scores from the judges.

Off-roaders

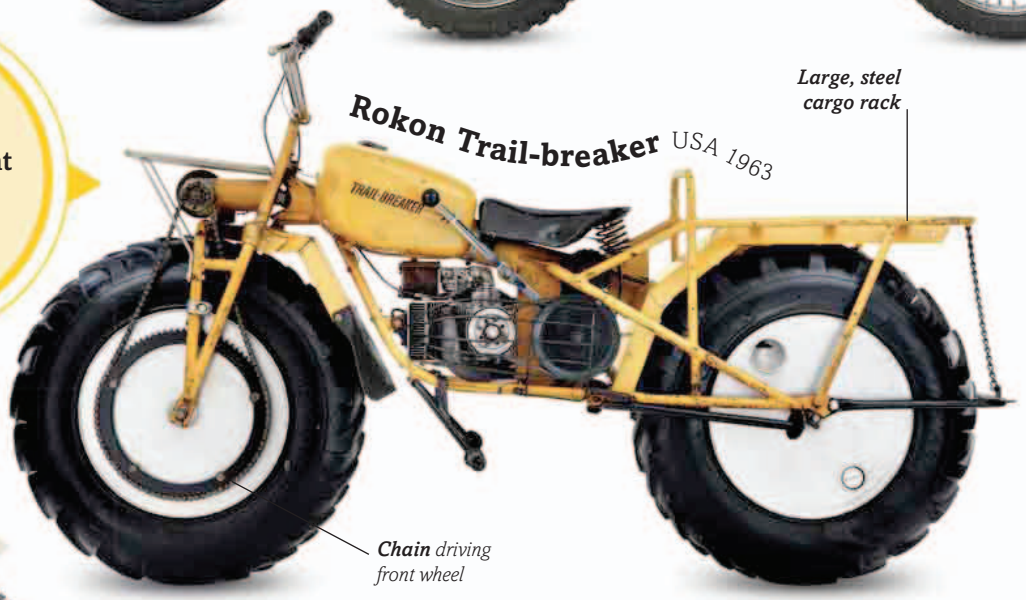
Harley-Davidson Hillclimber USA 1930

Raised mudguard *to keep mud and water from flinging up*

BSA Gold Star Scrambler UK 1959

Metal chains *wrapped around rear tire to grip loose ground*

Hollow aluminum **wheels** meant this motorcycle could **float** in water!



Rokon Trail-breaker USA 1963

Large, steel cargo rack

Chain *driving front wheel*

Husqvarna Enduro Sweden 1973

Race number

Knobbly, deep-tread tire *for gripping soft ground*

CZ 250 Motocross Czech Republic 1974

Road-legal bike weighs 240.3 lb (109 kg)

2.8 gal (10.6 liters) plastic fuel tank

Suzuki Enduro PE250X Japan 1981

Off-road motorcycles let you get away from the traffic, unless you are competing in a motocross race with 30 or 40 riders over a bumpy dirt course. Off-roaders are tough and strong, and equipped with plenty of suspension to soak up impacts.

The **Rokon Trail-breaker** is the only widely produced motorcycle to offer an all-wheel drive. Other off-roaders rely on rear-wheel drive and chunky tires with deep tread to grip sand or mud. The **KTM 65SX** is ideal for 8 to 13 year olds, but young riders may progress to a top motocross bike

Speedway bikes take under **3 seconds** to accelerate from **0–60 mph** (100 km/h).

Small tank *holds enough methanol fuel for four laps of racing*

Forks *steeply angled to give more response when steering*

Weslake Speedway UK 1981

Honda Africa Twin Japan 1990

Twin headlights

Motorcycle can travel 373 miles (600 km) on one tank of gas

Yamaha XT Tenere Japan 2010

KTM 65SX Austria 2011

Long-travel front forks

Aluminum exhaust silencer *tucked up under seat rear*

Motorcycle gives top speed of 50 mph (80 km/h)

KTM 350 SX-F Austria 2012

such as the **KTM 350 SX-F**. KTMs won the Motocross MX2 World Championships from 2008 to 2014. Enduro bikes, such as the lightweight **Suzuki Enduro PE250X**, race off-road but are usually used for competing over longer courses than motocross. Adventure motorcycles are big off-roaders with large fuel tanks, such as the **Yamaha XT Tenere**, which is based on the bike that won the Dakar Rally seven times. Speedway bikes, such as the **Weslake Speedway**, have no brakes and just one gear. They are raced in laps on a tight, oval dirt track in competitions.

Fastest on two wheels

A 1929 SS100 once sold for a record **£315,100** (about $460,000) at auction in the UK.

Engine's *two cylinders form a V-shape*

Excelsior 20R USA 1920

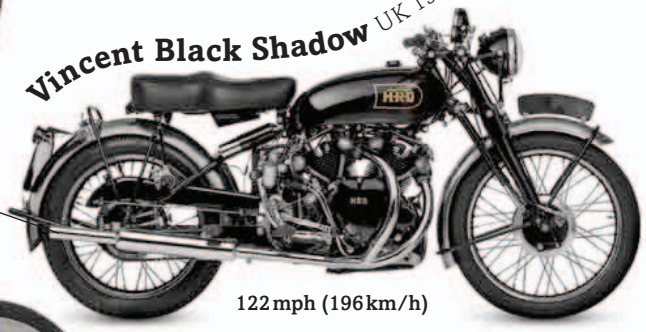
100 mph (160 km/h)

Pannier bags *for storage*

102 mph (164 km/h)

Brough Superior SS100
UK 1927

Vincent Black Shadow UK 1949

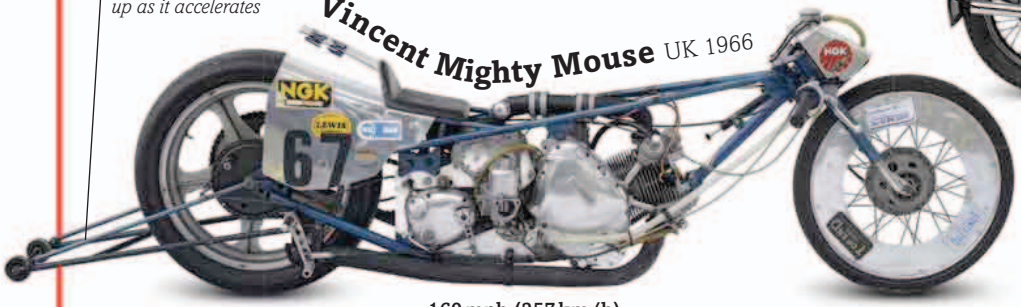


Single exhaust *from V-twin engine*

122 mph (196 km/h)

Wheelie bar *stops front of bike flipping up as it accelerates*

Vincent Mighty Mouse UK 1966



160 mph (257 km/h)

Body shell, *made of carbon fiber, is 21-ft (6.4-m) long*

Two Suzuki Hayabusa engines *power the bike*

367 mph (591 km/h)

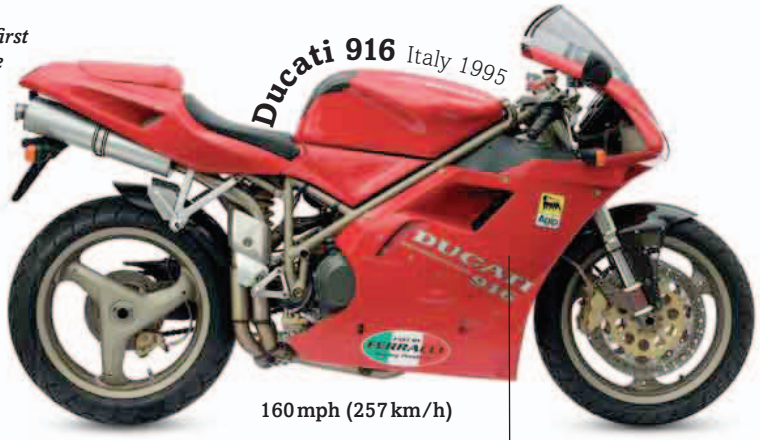
Ever since motorcycles were built, they have been raced or tested to see just how fast they would go. Designers, engineers, and riders would push everything to the limit to squeeze every drop of speed from their magnificent machines.

The **Excelsior 20R** was one of the first motorcycles to reach 100 mph (160 km/h). It was overtaken by the **Brough Superior SS100** and later the **Vincent Mighty Mouse**, which became the fastest single-cylinder motorcycle when it raced along drag strips in the 1960s. Most modern

BMW R90S
Germany 1975

Winner of the first AMA Superbike Championship in 1976

125 mph (200 km/h)



Ducati 916 Italy 1995

160 mph (257 km/h)

Streamlined fairing channels air past bike

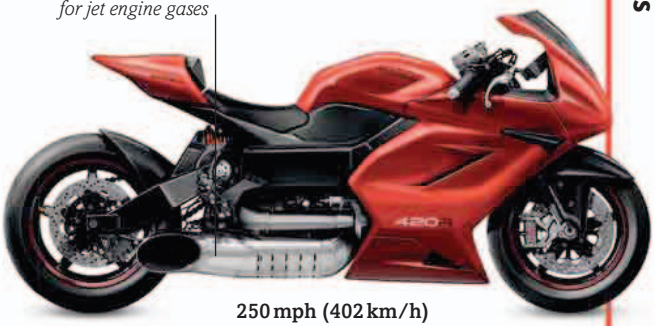
Hinged fuel tank lifts up for access to parts inside

186 mph (299 km/h)

Suzuki GSX 1300R Hayabusa
Japan 1999

Powerful disk brakes

Giant exhaust for jet engine gases



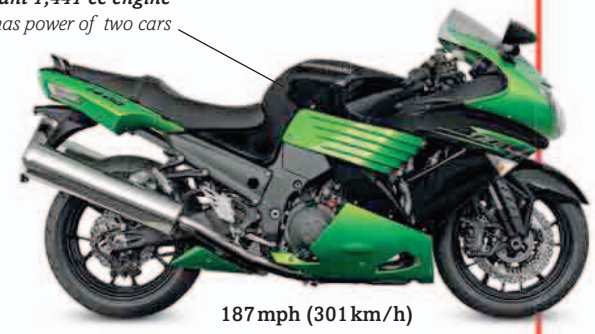
250 mph (402 km/h)

MTT Turbine Superbike
USA 2001

Giant 1,441 cc engine has power of two cars

Top 1 Ack Attack USA 2004

376 mph (606 km/h)

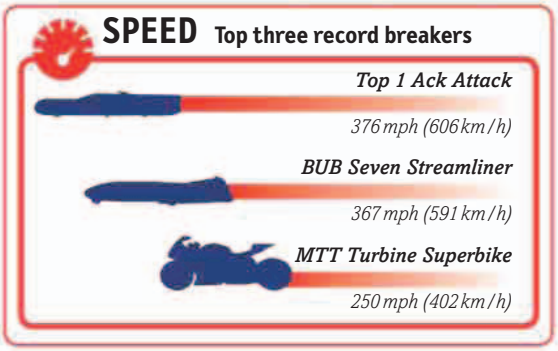


187 mph (301 km/h)

Kawasaki ZZR1400 Japan 2011

BUB Seven Streamliner USA 2006

SPEED Top three record breakers

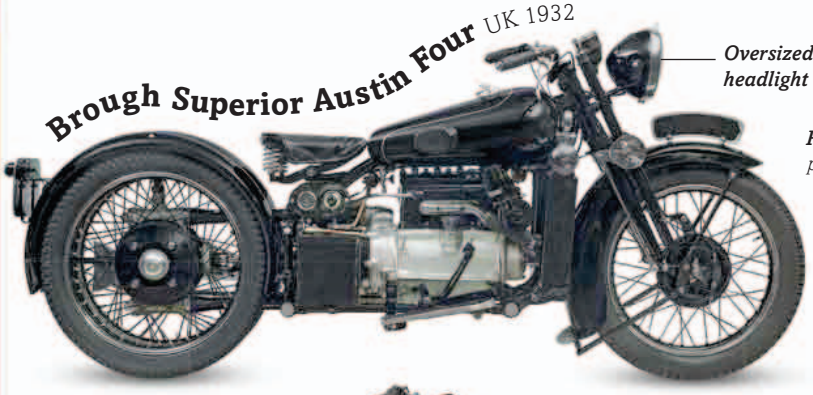


motorcycles have engines with multiple cylinders. The **Ducati 916** won four World Superbike Championships with its twin-cylinder engine, while the four-cylinder **Suzuki GSX 1300R Hayabusa** was the fastest production motorcycle of last century, and the **Kawasaki ZZR1400** is the fastest so far. Even faster are modern streamliners, motorcycles with low-slung aerodynamic bodies inside which riders lie flat. The **BUB Seven Streamliner** was the first to break 350 mph (563 km/h) in 2006, while the **Top 1 Ack Attack** is currently the world's fastest motorcycle.

Easy riders

Indian Two-Sixty USA 1914

Passenger seat perched over the rear wheel



Brough Superior Austin Four UK 1932

Oversized headlight

Sunbeam S7 De Luxe UK 1949

Fat tires for comfortable ride

Shaft from engine drives the rear wheel around

BMW R26 Germany 1957

Modified engines from the **R26** were used to power the **BMW Isetta 300** car.

Windshield height can be adjusted

Raised passenger seat

Chrome luggage rack

Harley-Davidson FLHT Electra Glide Classic USA 1984

Large, heavy, and powerful, touring and sports-touring motorcycles are designed for comfortable long-distance riding. Some of these big beasts are the last word in luxury, with high-quality audio systems and comforts not found on other bikes.

Early big motorcycles often copied features usually found in cars. The **Indian Two-Sixty** was the first bike to come with electric lighting as a standard feature. The **Brough Superior Austin Four** used an engine and a gearbox from a car to drive two closely set rear wheels for a smoother

***Cruise control** allows motorcycle to travel at set speed*

Honda Goldwing GL1500 Japan 1999

Suzuki M1800R Intruder Japan 2007

Harley-Davidson CVO Softail Convertible USA 2010

Cast aluminum front wheel

Carbon fiber body panels

***1,078 cc engine** gives top speed of 196 mph (315 km/h)*

MV Agusta F4CC Italy 2008

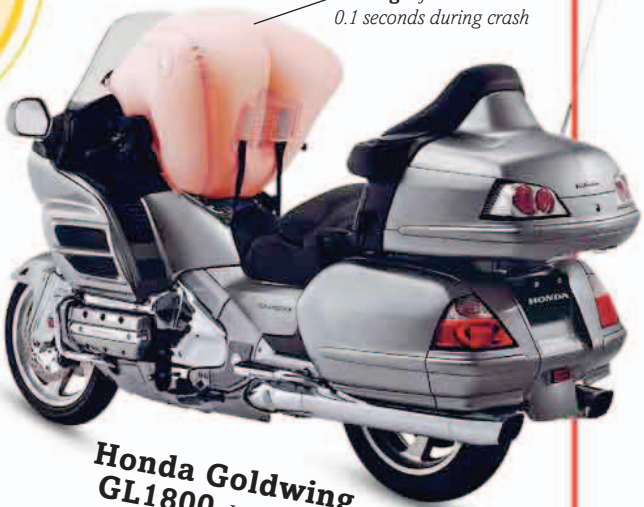
***Twin disk brakes**, normally found on racing motorcycles*

***Adaptive headlight** changes brightness according to conditions*

BMW K1600GT
Germany 2011

With a cost of **$300,000**, this motorcycle comes with a **$20,000** watch.

***Air bag** inflates in 0.1 seconds during crash*



Honda Goldwing GL1800 Japan 2014

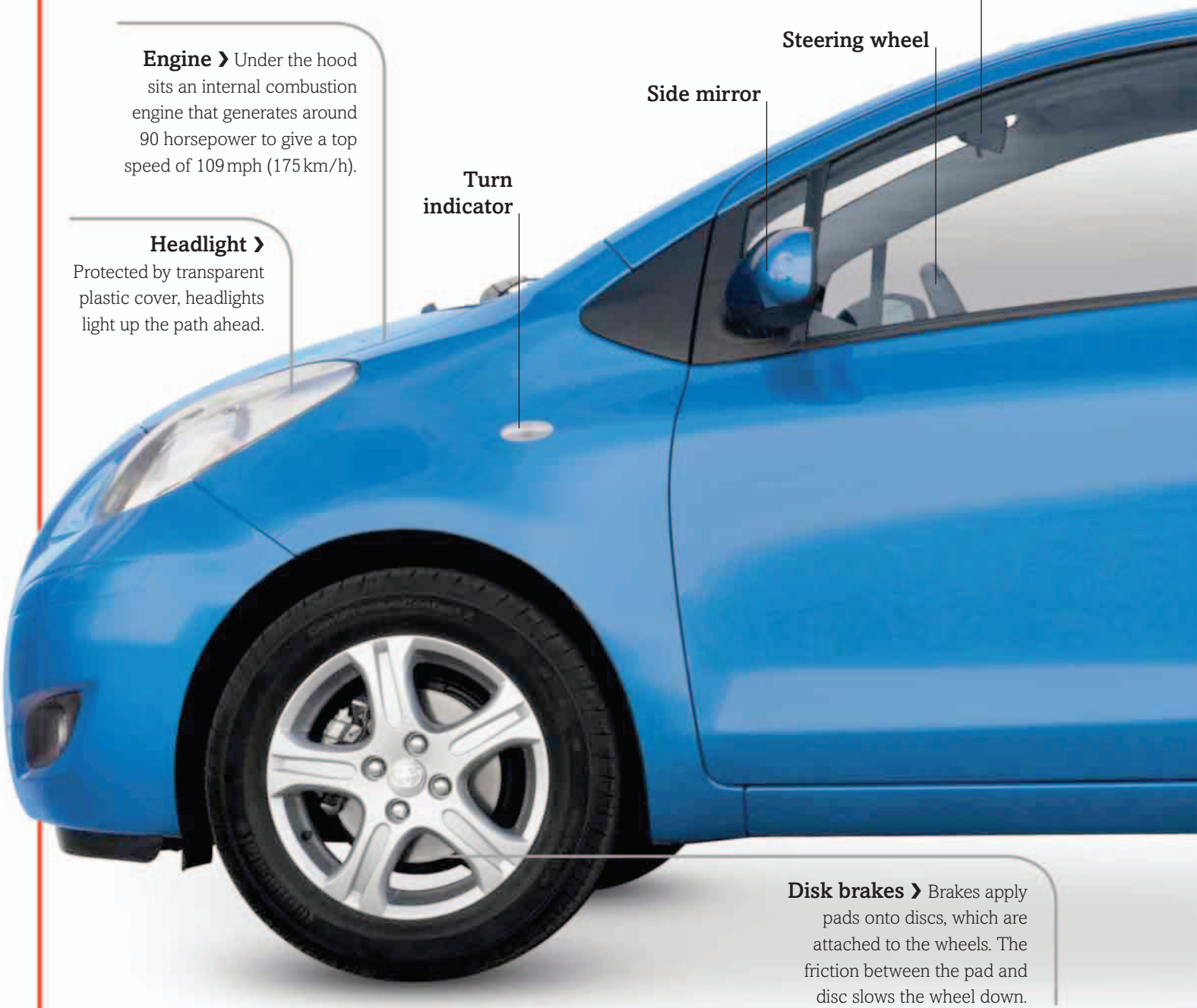
***Frame** made of light but strong titanium metal*

Ecosse Titanium
USA 2011

ride. In the 1970s and 1980s, big motorcycles got even larger and heavier. The **Electra Glide Classic** weighed more than 738 lb (335 kg) empty. Modern luxury motorcycles continue to offer innovative features. The **Honda Goldwing GL1500** comes with foot heaters and some feature a built-in jukebox. The **BMW K1600GT** has heated seats and handlebar grips for cold weather, and an onboard computer with a color touch screen. The **Honda Goldwing GL1800** has an electric reverse gear and an air bag for the rider.

Car

The car revolutionized transportation in the 20th century, and more than half a billion cars are found on the world's roads today. While some are powered fully or partly by electric motors, most cars use an internal combustion engine in which gas and air are mixed and burned to produce power to drive the wheels. The **Toyota Yaris** (or the *Vitz*) is a popular, small family car, with more than 200,000 manufactured every year.



Engine › Under the hood sits an internal combustion engine that generates around 90 horsepower to give a top speed of 109 mph (175 km/h).

Headlight › Protected by transparent plastic cover, headlights light up the path ahead.

Disk brakes › Brakes apply pads onto discs, which are attached to the wheels. The friction between the pad and disc slows the wheel down.

Hatchback › A full-height rear lifting trunk door gives this car 71.8 gal (272 liters) of storage space. Cars with a rear door like this are known as hatchbacks.

Interior › Inside the car, the driver and passengers are protected by a number of air bags, which inflate when there is a severe impact, to cushion the occupants. The Yaris has front and side air bags.

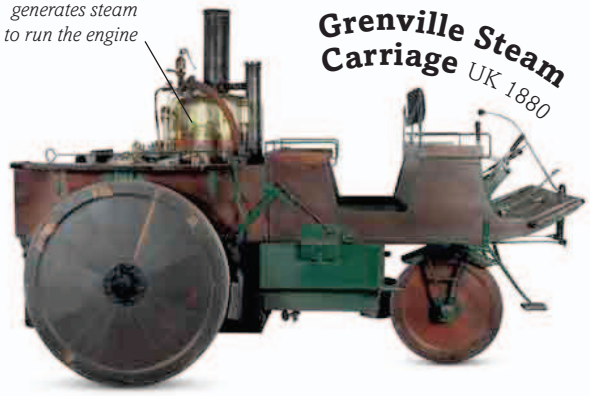
Radio antenna

Toyota Yaris/ *Vitz*

Rear indicator and brake light

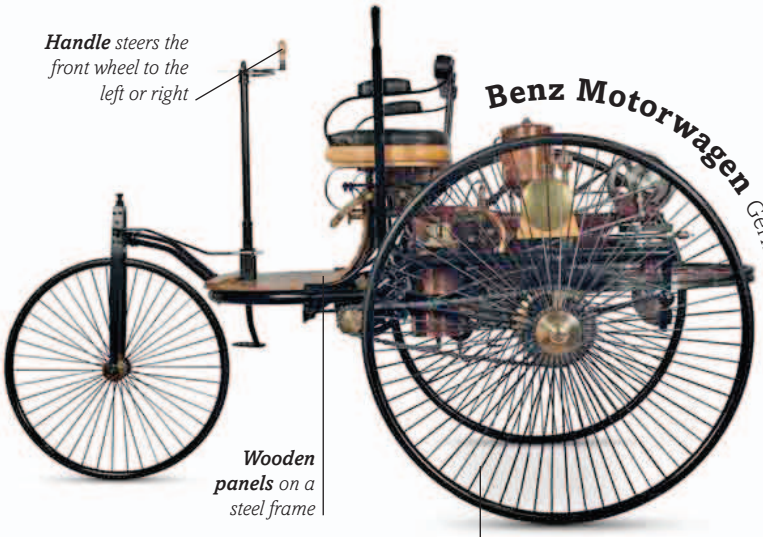
Passenger door › These are fashioned out of steel panels, aluminum, or carbon fiber. This car is fitted with remote central locking. The driver presses a button on the key to open or close the locks on all four doors.

Pioneering cars



Vertical boiler *generates steam to run the engine*

Grenville Steam Carriage UK 1880



Handle *steers the front wheel to the left or right*

Wooden panels *on a steel frame*

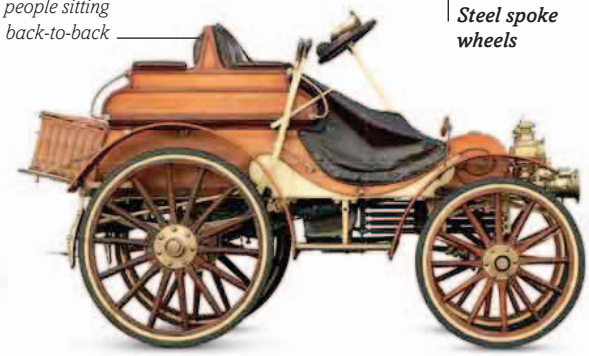
Steel spoke wheels

Benz Motorwagen Germany 1885

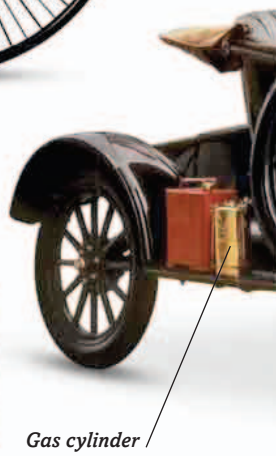
Daimler Germany 1886

Wooden spoked wheel

Seats *can fit six people sitting back-to-back*



Arrol-Johnston Dogcart UK 1897



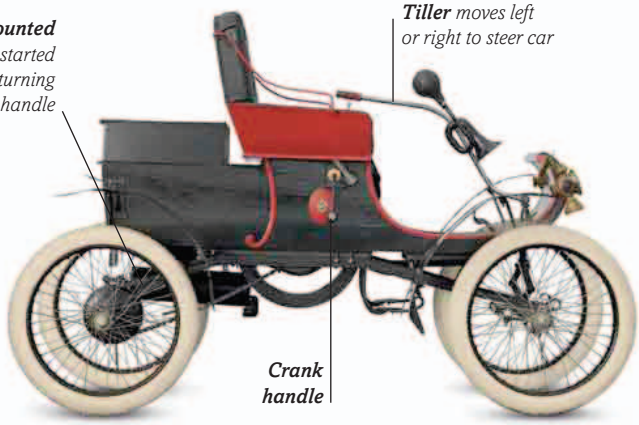
Gas cylinder

Horizontal steering wheel

Daimler Cannstatt
Germany 1898

Rear-mounted engine *started by turning crank handle*

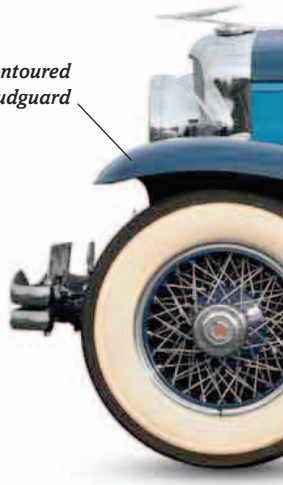
Tiller *moves left or right to steer car*



Crank handle

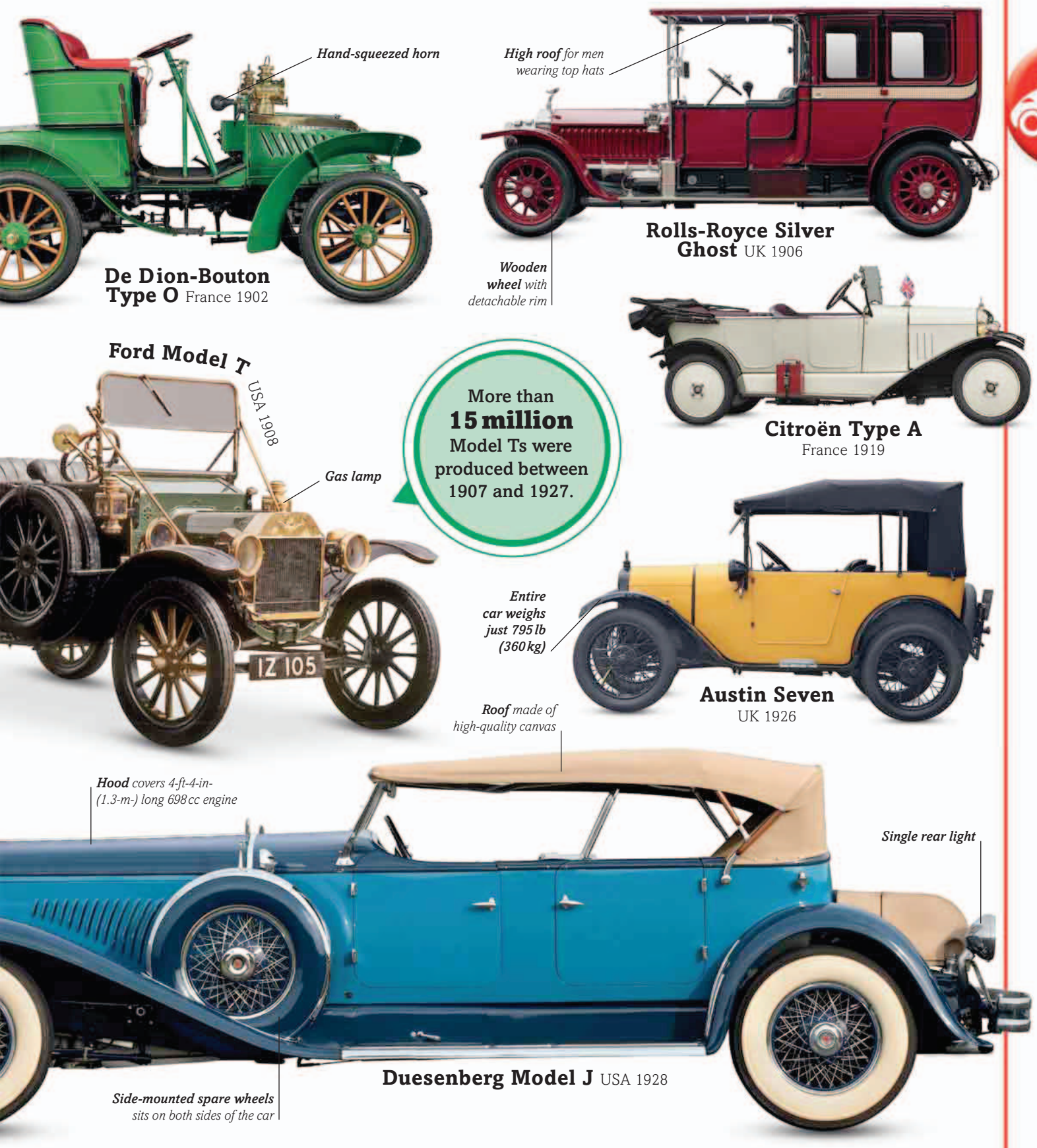
Oldsmobile Curved Dash USA 1901

Contoured mudguard



Early attempts to take to the road were in steam-powered vehicles, such as the Grenville Steam Carriage. It took the development of reliable internal combustion engines fueled by gasoline, to produce the first popular cars.

Karl Benz's three-wheeled **Benz Motorwagen** was the first car with a working internal combustion engine. A year later, the **Daimler**, a motorized horse carriage became the first gas-driven four-wheeler. While Daimler continued to develop motorized horse carriages, more car



makers emerged. The **Oldsmobile Curved Dash** was the world's first mass-produced car, with more than 19,000 sold. Some early cars had somewhat primitive features. The engine of the **Arrol-Johnston Dogcart** was started by pulling on a rope, and many cars, including the **Ford Model T**, had gas lamps. Built on an assembly line, the Model T made motoring affordable for the masses. The 1920s saw an explosion in car design, from the **Duesenberg Model J**, driven by American gangsters and movie stars, to the compact **Austin Seven**.

THRILLS AND SPILLS At first, this dramatic tangle of men and machines looks like a horrible accident. In fact, it's all fun and games. A clue is the ball on the ground on the right of the picture—and, if you look closely, you can see that the two passengers in the cars are wielding mallets. Welcome to the sport of "auto polo," and a crunch moment during a game in Florida, in 1928.

Polo is usually played by riders on horseback. In the USA in the early 1900s, the sport was spiced up a little when the horses were replaced with cars. It is said that the inventor was a Ford automobile dealer who came up with the idea as a publicity stunt, and it caught on. The game was played by two teams, each made up of two cars and four players, and their steeds were stripped-down Ford Model Ts. The driver was held in place with a seat belt, while his malletman leaned out and tried to hit a basketball into a goal. The cars tore around the field at furious speeds up to 40 mph (64 km/h), while the referee chased the action on foot. By the end of the game, most of the cars were destroyed.

Early race cars

Some early race cars had a **mechanic** onboard to make repairs.

85 mph (137 km/h)

Lancia Tipo 55 Corsa
Italy 1910

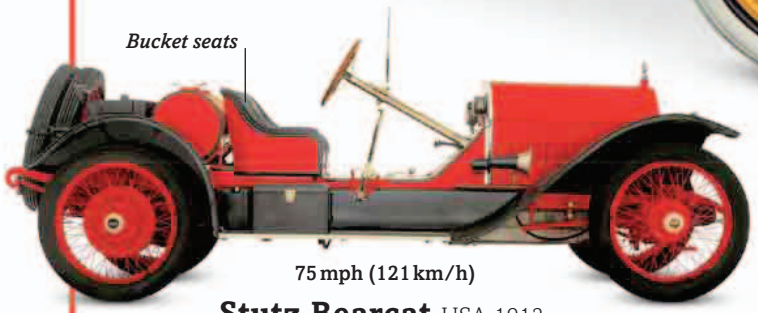
Small, round windshield known as a monocle

80 mph (129 km/h)

Mercer Type 35R Raceabout USA 1910

Starting handle turns to fire up engine

Bucket seats



75 mph (121 km/h)

Stutz Bearcat USA 1912

Duesenberg 183 USA 1921

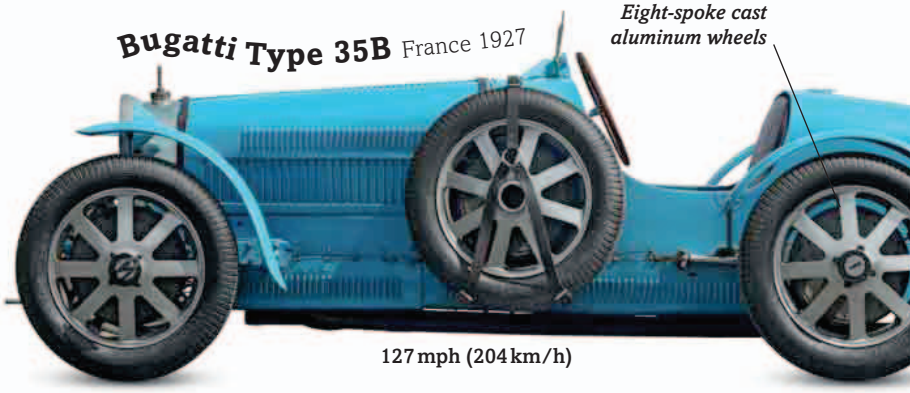
112 mph (180 km/h)

SPEED Top three rapid racers

Auto Union Type D	*205 mph (330 km/h)*
Mercedes-Benz W125	*205 mph (330 km/h)*
Maserati 8C 3000	*149 mph (240 km/h)*

Bugatti Type 35B France 1927

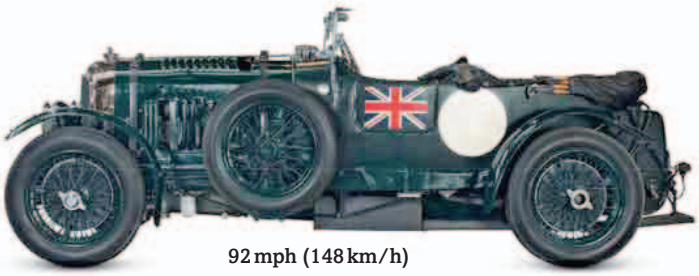
Eight-spoke cast aluminum wheels



127 mph (204 km/h)

As soon as cars were mass produced, people became eager to race them. Early racing tested speed as well as reliability, since early cars broke down a lot. But advances in technology quickly saw race cars develop into speed demons.

Some early race car drivers turned into car builders. Italy's Vincenzo Lancia, who won the 1904 Coppa Florio race, manufactured the **Lancia Tipo 55 Corsa**. Across the Atlantic, the **Stutz Bearcat** won 25 of the 30 races it entered, while the **Mercer Type 35R Raceabout** won



92 mph (148 km/h)

Bentley 4½ liter UK 1927

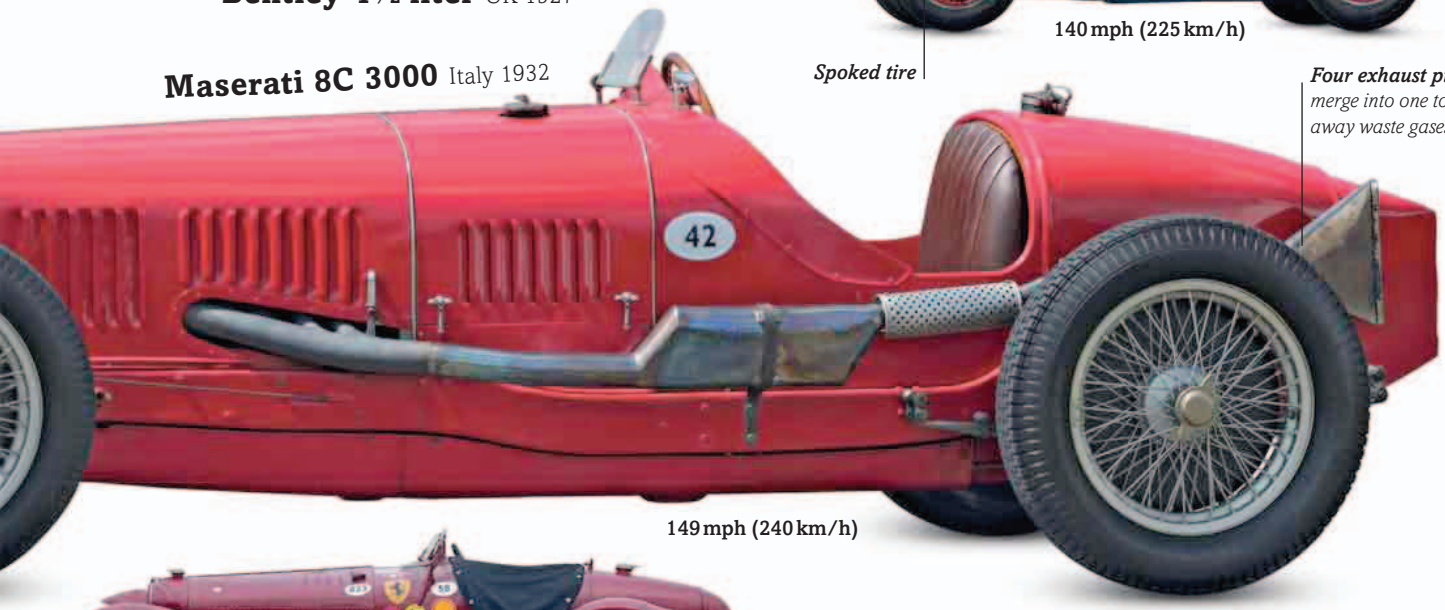
Miller Boyle Valve Special USA 1930

140 mph (225 km/h)

Spoked tire

Maserati 8C 3000 Italy 1932

Four exhaust pipes *merge into one to carry away waste gases*



149 mph (240 km/h)

Exhaust pipe *runs below cockpit*

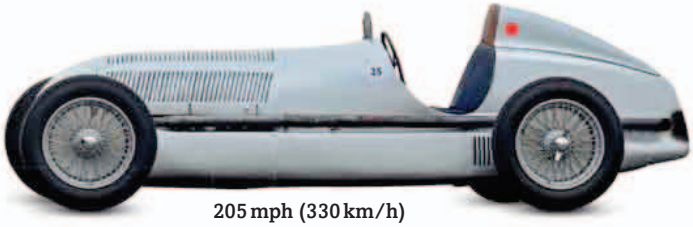
135 mph (217 km/h)

Alfa Romeo 8C 2300 Monza Italy 1933

Hudson Eight Indianapolis USA 1933

130 mph (209 km/h)

Hand brake lever *mounted outside*

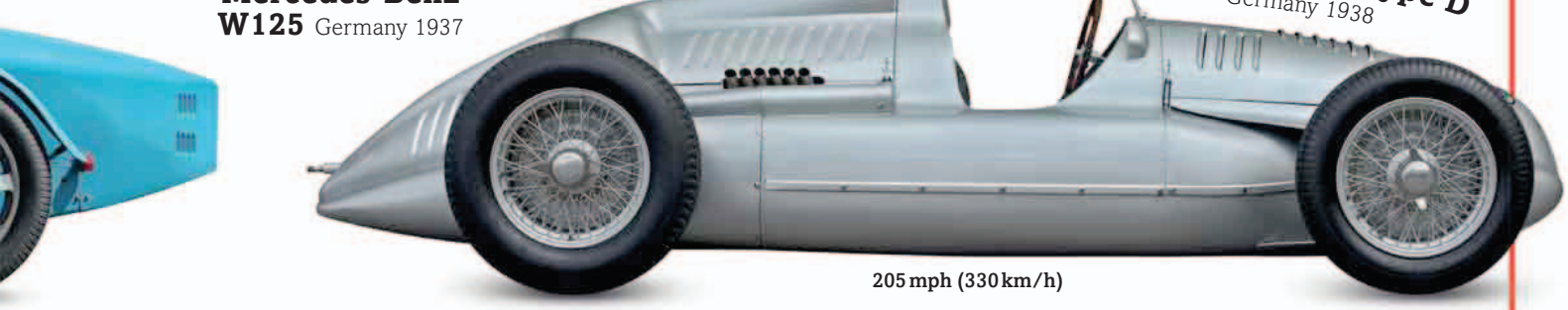


205 mph (330 km/h)

Mercedes-Benz W125 Germany 1937

Engine mounted behind driver

Auto Union Type D Germany 1938

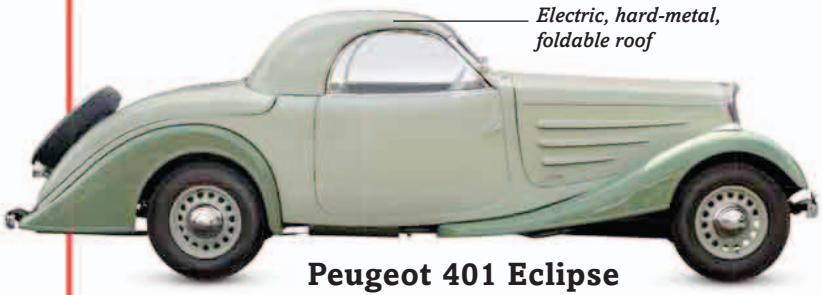


205 mph (330 km/h)

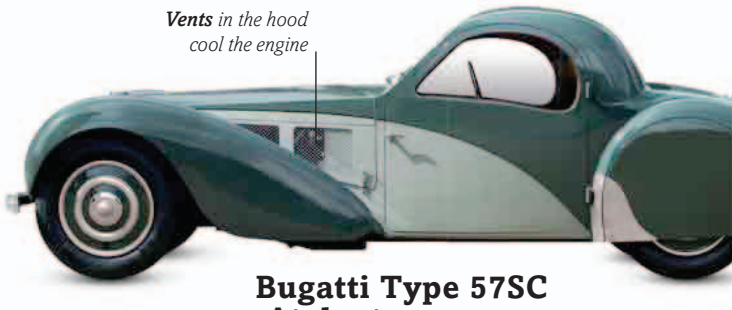
five of its first six races in 1911. Race cars remained box-shaped until after World War I, when sleeker, more rounded shapes started to emerge. In 1921, the **Duesenberg 183** became the first all-American car to win a Grand Prix race in Europe. Stunning speedsters, such as the **Alfa Romeo 8C 2300 Monza** and the **Bugatti Type 35B**, were produced throughout the 1920s and 1930s. Type 35 cars won more than 1,000 races and battled it out with German cars such as the **Mercedes-Benz W125**, which dominated at the 1937 European Grand Prix Championship.

Machines with style

Mercedes-Benz 500K Special Roadster Germany 1934



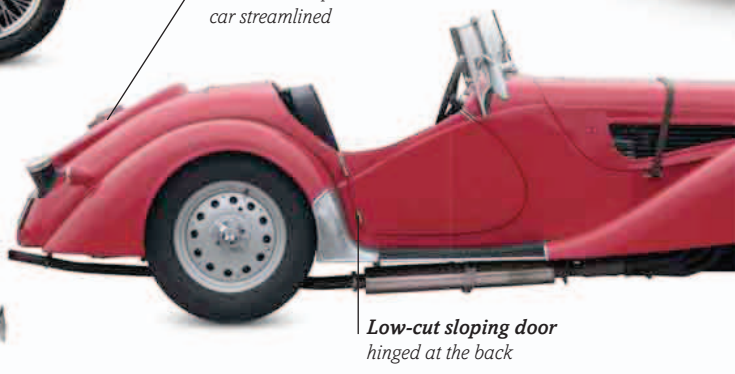
Peugeot 401 Eclipse
France 1934



Bugatti Type 57SC Atalante France 1935

Auburn Speedster USA 1935

MG TA Midget UK 1936



BMW 328 Germany 1936

Lincoln-Zephyr USA 1936

In the 1930s, some cars got slick and sleek as research revealed the importance of airflow around a car, especially at higher speeds. Streamlining vehicles to improve performance resulted in some stylish and eye-catching designs.

The **Lincoln-Zephyr** created a sensation at the 1936 New York Auto Show with its teardrop shape. On the road, the **Auburn Speedster** roared with a 148 horsepower engine that generated a top speed of around 100 mph (160 km/h). While some European sports cars

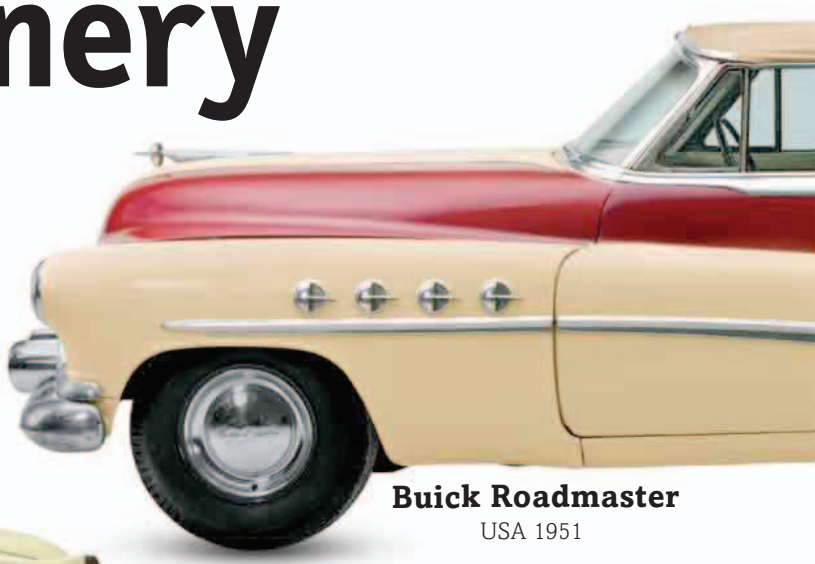
stayed boxy, such as the **MG TA Midget**, others like the **Alfa Romeo 8C 2900B Coupé** were designed with sweeping, rounded body shapes. The exotic **Peugeot 402 Darl'Mat** showcased extreme streamlining with a lightweight aluminum body and an advanced gearbox.

The sleek **Mercedes-Benz 500K Special Roadster** was packed with advanced features for its time, including electric door locks, turn indicators, hydraulic brakes, and separate suspension systems for each wheel for a comfortable ride.

Fins and finery

Rear compartment *seats four people on two rows of facing seats*

Mercedes-Benz 300 Germany 1951

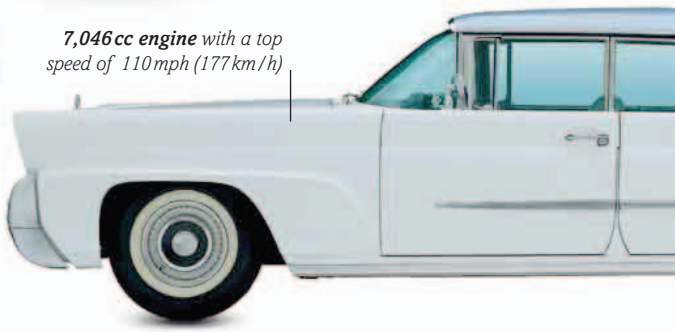


Buick Roadmaster
USA 1951

Cadillac Series 62 Club Coupé USA 1952

Big fins *were pioneered by Cadillac*

7,046cc engine *with a top speed of 110mph (177km/h)*



Armstrong Siddeley Sapphire UK 1953

Front doors *open at the back, the opposite way of the rear doors*

Large tailfin *contains the gas cap of the 23-gal (87-liter) gas tank*

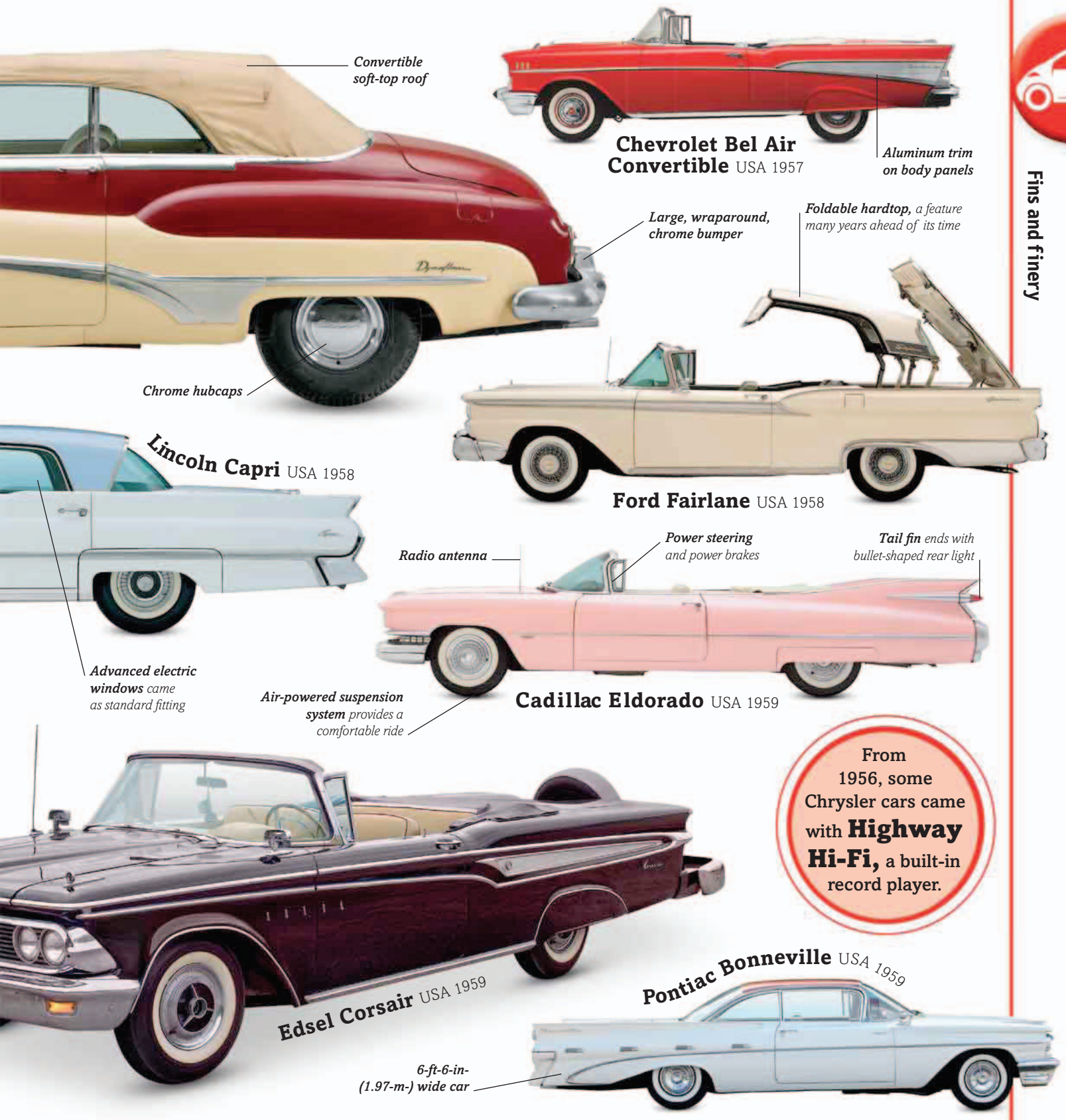
Chrysler New Yorker
USA 1957

Large tail fin *rises up from main body*

Studebaker Silver Hawk USA 1957

The 1950s saw an incredible economic boom in the USA; 30 million more cars had taken to its roads by the end of the decade. Cars went from everyday transportation to chrome-covered status symbols, packed with innovative new features.

Germany's first postwar luxury car, the **Mercedes-Benz 300**, seated six people and was called the ***Adenauer*** after the West German chancellor who installed a writing desk inside one of his 300s. In contrast, the American **Buick Roadmaster** was a riot of two-tone color and



chrome, including chrome engine vents. The USA had entered the jet-aircraft age and this was reflected in the design of many cars—such as the **Pontiac Bonneville,** with its futuristic styling and large tail fins. Some cars also grew in length. The **Chrysler New Yorker** was more than 18 ft (5.5 m) long, while the **Lincoln Capri** was even longer at over 20 ft (5.8 m). Automatic transmission was popular in big cars such as the **Chevrolet Bel Air Convertible,** which also had fuel injection and luxurious styling. It remains one of the most collectable cars from the fifties.

Faster and faster

Race car design developed greatly from the 1950s onward. Engineers and designers were constantly looking for improvements to increase speed, enhance handling, and boost performance in order to be the first to cross the finish line.

Track racing began in the 1950s with mostly front-engined race cars, such as the **Maserati 250F** and the **Mercedes-Benz W196**, which won the Formula 1 (F1) Championships in 1954 and 1955. By the end of the 1950s, rear-mounted engines became all the rage in

Ford GT40 MKII USA 1966

Lotus 49 UK 1967

Lola-Cosworth T500 UK 1978

***Nose** fitted with low front wing*

Benetton-Ford B193 UK 1993

Carbon fiber body

Adjustable rear spoiler

Holden VR Commodore SS Australia 1993

Williams-Renault FW18 UK 1996

Williams-Renault FW18 won **12** of the **16 F1 races** in 1996.

***Windshield** clipped in for easy removal*

***Large, aerodynamic wing** keeps the car stable at high speed*

Chevrolet Monte Carlo USA 2000

***3,000 cc engine** gives top speed of 220 mph (354 km/h)*

***Front wing** ensures car grips the track*

F1 and Indy Cars. Sports car racing also saw change. Open cockpit cars such as the **Jaguar D-Type**, which won the Le Mans 24-hour endurance race in 1955, 1956, and 1957, were replaced by cars with a roof. The sleek **Ford GT40 MkII** finished first, second, and third at Le Mans in 1966. In some parts of the world, track racing featuring modified sedan cars gained popularity. A **Holden VR Commodore SS** won the 1995 Australian Touring Car Championships, while the **Chevrolet Monte Carlo** was driven by many NASCAR racers.

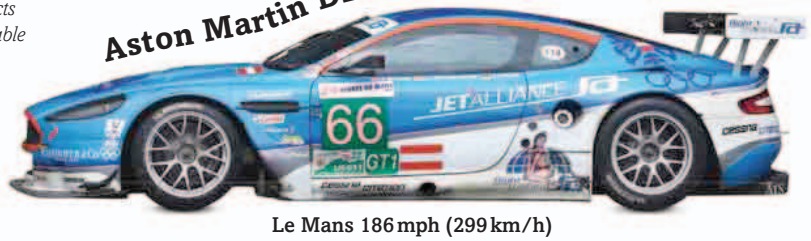
Fast and furious

Bentley Speed 8 UK 2001

Rear wing deflects air to keep car stable

Le Mans 205 mph (330 km/h)

Aston Martin DBR9 UK 2005



Le Mans 186 mph (299 km/h)

Powerful headlights for nighttime racing

Audi R10 Germany 2006

Le Mans 211 mph (339 km/h)

Radio transmitter sends information about the car's performance to race team

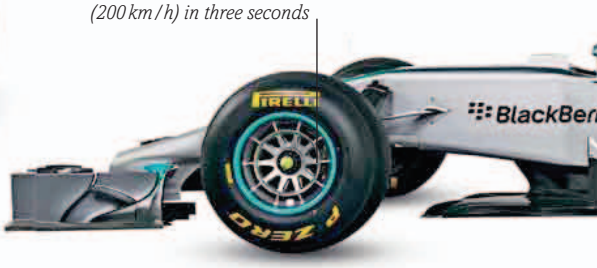
Roll cage frame protects driver if car rolls over

BMW M3 GT2 Germany 2008

Le Mans 180 mph (290 km/h)

Ferrari F2008 Italy 2008

Powerful disk brakes can stop a car at 125 mph (200 km/h) in three seconds



Modern high-speed racers packed with electronics are designed and modeled on computers, and tested in wind tunnels to ensure their design offers maximum performance. No expense is spared on these sleek speed machines.

All successful race cars must be fast, but different forms of racing place different demands on the vehicle. A power-packed rally car must be rugged and able to handle roads, tracks, and rough ground. The World Championship winning **Volkswagen WRC Polo R** can accelerate from

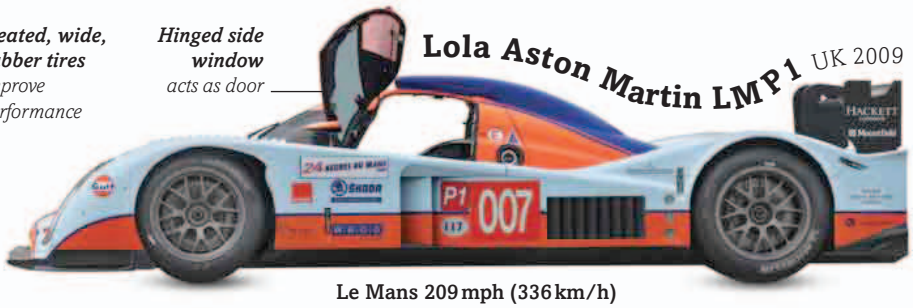
Formula 1 200 mph (322 km/h)

McLaren-Mercedes MP4/23 UK 2008

Heated, wide, rubber tires improve performance

Hinged side window acts as door

Lola Aston Martin LMP1 UK 2009



Le Mans 209 mph (336 km/h)

Chevrolet SS USA/Australia 2013

Large roof flaps lift up to ground car during crash

NASCAR 196 mph (316 km/h)

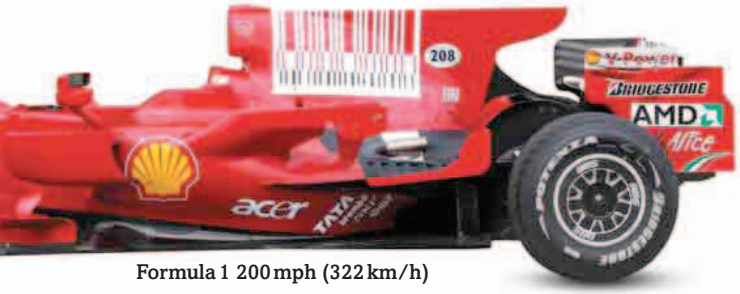
F1 drivers **shift gears** more than **3,600** times in a Grand Prix race.

Indycar Series 230 mph (370 km/h)

Team Penske Dallara/Chevrolet USA 2014

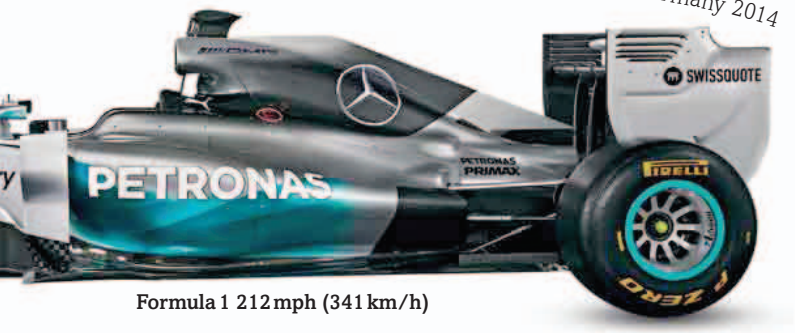
Volkswagen WRC Polo R Germany 2014

Rally 125 mph (201 km/h)



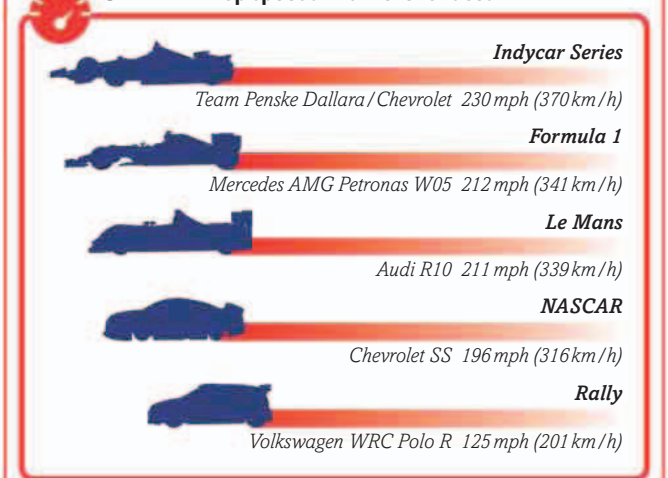
Formula 1 200 mph (322 km/h)

Mercedes AMG Petronas W05 Germany 2014



Formula 1 212 mph (341 km/h)

SPEED Top speeds in different races

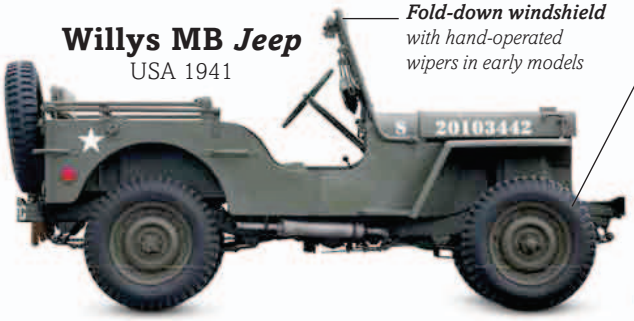


0–60 mph (0–100 km/h) in 3.9 seconds. Cars built for endurance racing must be very reliable. In 2009, the **Lola Aston Martin LMP1** raced 3,159 miles (5,084 km) in 24 hours at Le Mans. Its driver, Tom Kristensen, also won the race a record nine times in the **Bentley Speed 8** and the **Audi R10**. Danica Patrick, in a **Chevrolet SS**, became the first woman to win pole position for NASCAR's Daytona 500. Lewis Hamilton won the World Championship with the **McLaren-Mercedes MP4/23** in 2008, and again in 2014, with the **Mercedes AMG Petronas W05**.

THE ULTIMATE TEST Powering through giant sand dunes, some more than 66 ft (20 m) high, is just one of the many challenges facing this Monster Energy X-Raid Mini in the 2013 Dakar Rally. Considered the toughest test of car and driver on the planet, competitors race across more than 5,280 miles (8,500 km) of the toughest terrain imaginable, from rocky pavements to giant deserts and forest trails.

The Dakar was first held in 1979 across the unforgiving Sahara in Africa, but since 2009 it has run through South America. More than 400 cars, motorcycles, quad bikes, and trucks take part in each race, but fewer than 60 percent of these reach the finish line. This Mini is built tough and equipped with four-wheel drive, a powerful engine giving it a 111 mph (178 km/h) top speed, and tanks able to hold up to 106 gallons (400 liters) of gas. Driver Stéphane Peterhansel is a Dakar legend. He won the motorcycle class of the rally six times before switching to cars. Over two solid weeks of phenomenal off-road racing in his Mini, Peterhansel won the 2013 Dakar—his fifth victory in the car class.

Fun in cars



Willys MB *Jeep* USA 1941

Fold-down windshield *with hand-operated wipers in early models*

Chunky-tread tire *provides grip over rough ground*

Mini Moke UK 1964

Rear spoiler

Leyland Mini Moke Australia 1968

Small 9¾in- (25 cm-) diameter wheel

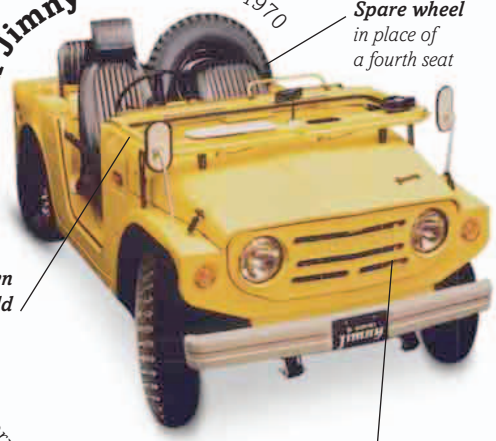
Steel side box *holds car battery*

Dune Buggy USA 1960s

Bucket seats with harness *to keep driver and passenger secure*

Between 1960 and 1980, every **second car** on Magnetic Island, Australia was a Mini Moke.

Suzuki Jimny LJ10 Japan 1970



Spare wheel *in place of a fourth seat*

Fold-down windshield

Grille *lets air into engine compartment*

Volkswagen Beetle Baja Bug Germany 1970s

Toughened body *for rallying*

Strong towing bar *to pull car out if stuck in sand or mud*

Ford Escort RS1800 UK 1973

Driving can be enjoyable, but some cars are more fun than others! A number of cars have been modified or designed from scratch to offer a fun drive on open roads, across stretches of sand, or along trails and rally courses.

The **Willys MB *Jeep*** could be driven just about anywhere, with more than 600,000 produced during World War II. Civilian Jeeps followed until 1986 when they were replaced by the **Jeep Wrangler**, which allowed drivers to switch between two- or four-wheel drive. Several fun

Peugeot 205 T16 Evo 2 France 1985

Gas cap of 76.6-gal (290-liter) gas tank

V12 engine from a Lamborghini Countach supercar

Lamborghini LM002 Italy 1986

Steel half-door

Spare wheel

Rear door for passengers to enter

Jeep Wrangler USA 1987

Heavy-duty suspension to withstand bumps

MCC Smart Crossblade France 2002

Cut-out sides offer open-air driving

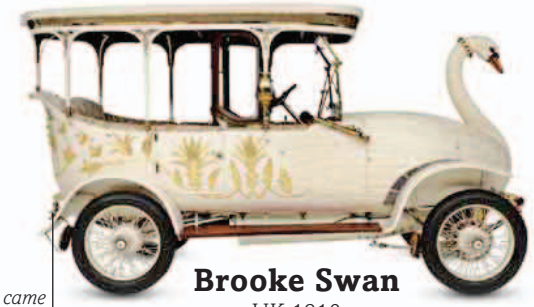
Doors are optional on this two-seater

Secma F16 Sport France 2008

The Crossblade has **no doors**, **no windshield**, and **no roof**.

cars started life as military prototypes, such as the **Lamborghini LM002**, an off-roader with four-wheel drive, air conditioning, and a roof-mounted stereo. The **Leyland Mini Moke**, on the other hand, was a bare-bones vehicle with no frame around the driver. **Dune Buggies** were tailor-made for beaches, while some modified cars, such as the **Baja Bug**, had raised bodies and strong suspensions to overcome the most difficult terrains. Buggy-styled cars are still made today, such as the **Secma F16 Sport**, which has plastic body panels and a convertible roof for rainy days.

Crazy cars



Brooke Swan UK 1910

Whitewash came out of the back to simulate bird droppings

Lightweight plywood body

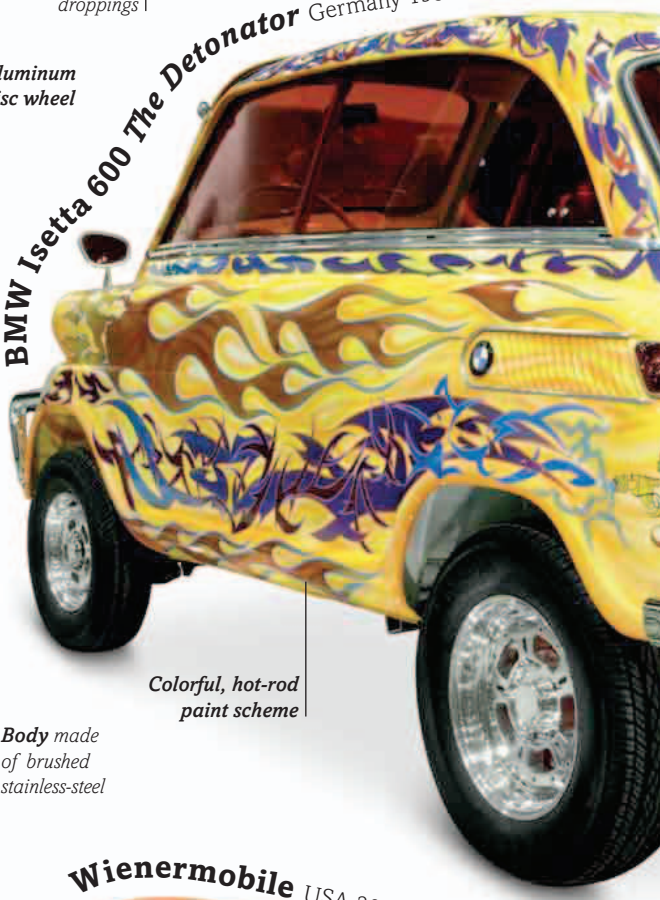
Aluminum disc wheel

Leyat Hélica France 1919

34-ft- (10.4-m-) long wings

Aerocar USA 1954

BMW Isetta 600 The Detonator Germany 1958



Colorful, hot-rod paint scheme

This **James Bond** car can race in reverse gear at speeds above 112 mph (180 km/h).

Gull-wing doors

Body made of brushed stainless-steel

DeLorean DMC-I2 UK 1981

Wienermobile USA 2004

Aston Martin Vanquish UK 2002

Machine guns

Rockets fire from radiator grille

Think all cars are simple, straightforward boxes-on-wheels? Think again! Over the years, designers and engineers have let their imaginations run wild, and some outrageous and surprising designs have left the drawing board and turned into reality.

Some of these wacky machines, such as the **Brooke Swan**, which hissed hot water and steam out of its beak, were special one-of-a-kind models built for eccentrics, or for movies such as the **Batmobile *Tumbler***. The **Flatmobile**, however, was made to break records. At just 19 in (48.2 cm)

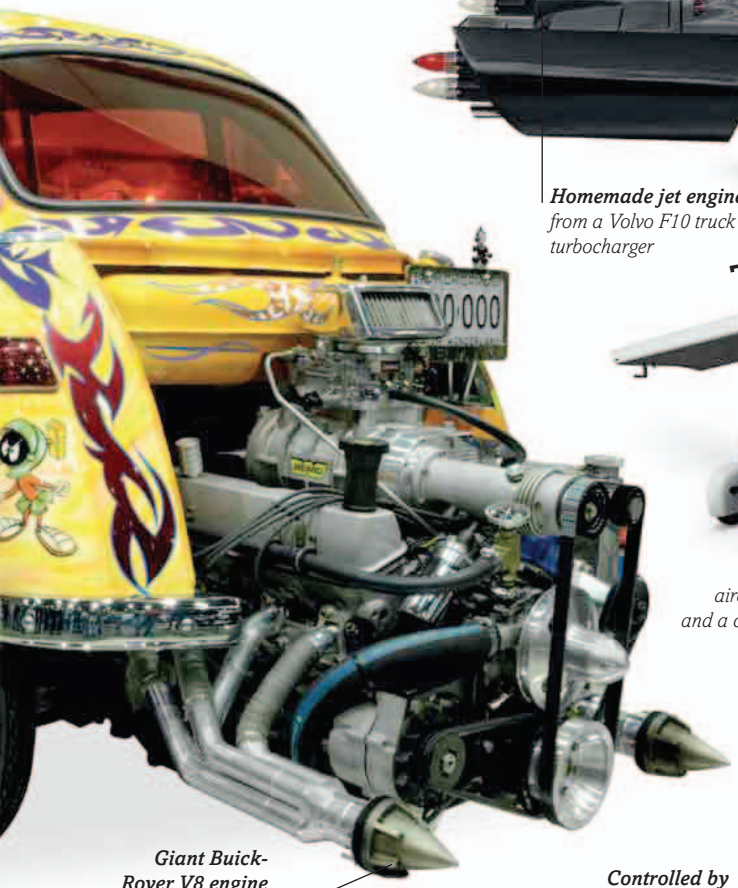
Batmobile *Tumbler* USA 2005

Four rear tires

LOWEST STREET CAR

Flatmobile UK 2007

Homemade jet engine *from a Volvo F10 truck turbocharger*



Giant Buick-Rover V8 engine *fitted to the rear*

Terrafugia Transition USA 2009

Electromagnets *lock wings into place*

Cockpit *has an aircraft control stick and a car steering wheel*

The Transition can **convert** from a car to a plane in less than **60 seconds**.

Toyota FV2 Japan 2013

Controlled by driver's body movements

Cab *shaped like a hot dog*

Onda Solare Emilia 3 Italy 2013

Small cockpit pod

Solar panels *produce more than 1,200 watts of electricity to drive motors*

tall, it is the lowest street-legal car in the world. Flying cars are among the craziest of all, but the **Aerocar** and **Terrafugia Transition** did work, using folding wings and a pusher-propeller at the rear to thrust the car forward. The **Leyat Hélica** couldn't fly but was pushed into action by an aircraft propeller and could reach speeds of up to 106 mph (170 km/h). Some strange-looking cars are experiments to test out new ideas, such as the solar-powered **Onda Solare Emilia 3**, or the **Toyota FV2**, whose body can change color to reflect the driver's mood!

A SPIN ACROSS THE WAVES

Is it a car? Is it a boat? The answer is it's both!

The WaterCar Panther is an American amphibious vehicle equally at home on water as it is on land. When on a lake, river, or bay, its engine powers jet thrusters that suck in water and then push it out behind the craft, propelling it forward at speeds up to 43 mph (70 km/h).

On the road, the car's 1-gal (3.7-liter) Honda Acura engine powers the Panther's rear wheels, giving it a top speed of around 80 mph (128 km/h). The 15-ft- (4.6-m-) long waterproof, Jeep-shaped body can carry four people and is sculpted out of fiberglass fitted to a steel frame. Parts of its body are filled with incredibly lightweight Styrofoam to help it float. When reaching the water, the driver only has to pull a knob to engage the jet thrusters, and press a button. The Panther does the rest, using its hydraulic suspension system to retract its wheels up into its body. This all takes under 15 seconds! Once on the water, the Panther can glide with ease and can even tow a water-skier or wakeboarder.

Family cars

Volkswagen Kombi Germany 1950

Hillman Imp UK 1963

The Cortina was the **UK's bestselling** car from 1972 to 1981.

Ford Cortina MK I GT UK 1963

Chrome hubcaps

Oldsmobile Starfire USA 1964

Austin Maxi 1750 UK 1969

Morris Marina UK 1971

A family car needs to be economical and have space for four to five people, as well as for plenty of storage. Many manufacturers work hard to build affordable cars that have the perfect balance of space, performance, and price.

Family cars in the 1960s, such as the **Oldsmobile Starfire**, were often based on a three-box design, with an engine compartment, passenger cabin, and large trunk. The **Hillman Imp** changed things by putting the engine in the rear, while early hatchbacks, such as the **Austin Maxi 1750**,

came with a sloping rear door to offer more versatile storage space. The affordable **Morris Marina** was built to compete with the highly popular **Ford Cortina**, which was bought by more than two million customers, mostly in the UK. Sleeker family cars appeared from 1970s, with more hatchbacks such as the **Fiat Strada/Ritmo**—and the **Volkswagen Golf GTI**, which launched a new class of cars, the "hot hatch." These offered a hatchback design with a faster, sportier output than most family cars. More than 29 million Golfs have been built to date.

Outdoor warriors

Spyker 60HP
Netherlands 1903

Wheels powered by 8-liter engine

Low height to enable easy loading of cargo

Jeep Wagoneer USA 1972

Rear seats fold down to create large cargo space

Subaru Leone Estate Japan 1972

Car switches between four- and two-wheel drive

Top speed of 154 mph (248 km/h)

Audi Sport Quattro Germany 1983

Low rear spoiler

Daihatsu Sportrak Japan 1987

Small 7ft 2in (2.2m) wheelbase

Turbocharger boosts engine power to 185 horsepower

Lancia Delta Integrale
Italy 1987

STEEP CLIMB

Most 4x4s can climb at angles up to 45°

Most cars transmit power from their engine to either the front or rear wheels, but not four-wheel drives. Known as "4x4s," these cars direct power to all four wheels, offering better grip on slippery roads and tricky off-road conditions.

In 1903, the **Spyker 60HP** used the first four-wheel drive on a gasoline-fueled car. However, only military and special purpose off-road 4x4s, such as Land Rovers, were built in large numbers until the 1960s and 1970s. The **Subaru Leone Estate** was one of the first everyday 4x4s. It was

The H3 was the **smallest** among the Hummer models, and the **only** one to be built by **GM**.

designed mainly for driving on roads in all conditions, with some light, off-road action. In the 1980s, rallies became dominated by fast, rugged 4x4s, such as the **Lancia Delta Integrale** and the **Audi Sport Quattro**, which won many World Rally Championship titles between them. By then, the first sports utility vehicles (SUVs) had emerged. These rugged cars, like the **Daihatsu Sportrack** and **Volvo XC90**, had high-set bodies for better ground clearance over bumpy roads. The **Hummer H3** can travel through 24 in (60 cm) of deep water and drive up 60-degree slopes.

Convertibles and sports cars

Fast to accelerate and quick to brake, sports cars are built to thrill. Mostly two-seaters, they offer higher performance and sharper handling than everyday cars. Convertibles have a folding roof for open-top driving on sunny days.

There's no mistaking the love for sports cars—old and new! The first generation of **Chevrolet Corvettes** were built in 1953 and the seventh generation came out in 2014. More than 820,000 high-performance **Porsche 911s** have been built, while **Ford Mustang Fastbacks** were

among the two million Mustangs sold in the first two years of production. Many Mustangs in the late 1960s and 1970s were fitted with large V8 engines to offer the brute force provided by fellow muscle cars such as the **Pontiac Trans Am**. Sports cars fitted with smaller engines, even if not as powerful and fast, also proved fun to drive due to their light weight. The **Mazda MX-5** weighed 1,962 lb (890 kg), while the **Lotus Elise** tipped the scales at just 1,598 lb (725 kg). The popular British soft-top **MGB Convertible** sold half a million models in the UK alone.

Mini motors

Small is beautiful when you need a car to dodge and weave through narrow city streets, and to squeeze into the smallest parking spaces. Light in weight and easy on the pocket, their small engines make these mini motors cheap to run.

Partly inspired by the success of the **Volkswagen Beetle**, a wave of tiny cars hit the roads in the 1950s and 1960s. The compact **Messerschmitt KR200** could accommodate only a driver and one passenger, while the egg-shaped **BMW Isetta 300** had two front wheels placed close

together, no hood, and a motorcycle engine tucked behind the seat. Many three-wheeled cars, such as the **Reliant Robin** and the **Frisky Family Three**, could be driven on a motorcycle license. While the Frisky sold only in hundreds, the sales of the hugely popular **Austin Mini Seven** reached more than four million by 1976. Today, mini cars such as the **Smart City-Coupé** and the **Tata Nano** are popular in crowded cities. However, all of them still dwarf the **Peel P50**, the world's smallest car, which weighs a mere 130 lb (59 kg).

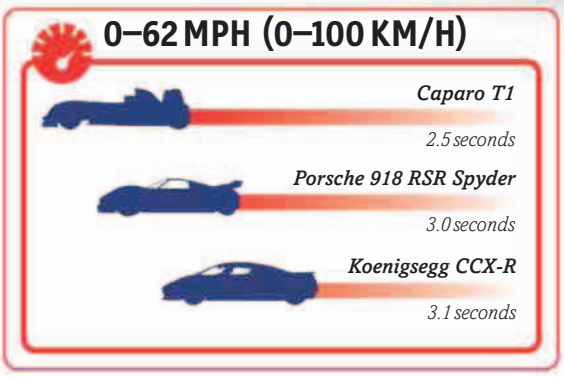
THE MOPETTA MICROCAR

In 1958, the passionate German car designer Egon Brütsch decided he was going to build the world's smallest car for the International Bicycle and Motorcycle Exhibition in Frankfurt that year. His idea was to use a new material called fiberglass to make two shell-like panels, which would fit together to form an egg-shaped microcar.

Brütsch built the prototype of the Mopetta overnight, but he did not have time to sort out the mechanics before the exhibition, so the microcar was displayed up high, away from prying eyes. Success at the show meant Brütsch then had to make his design work. The result was a single-seat three-wheeler that was 5 ft 7 in (1.75 m) long, 3 ft (0.9 m) wide, and had a 50 cc engine that took it to a top speed of 22mph (35 km/h). With its fiberglass body, Brütsch thought the car would also work as a boat. Although publicity photographs showed the Mopetta crossing a shallow stream, it could never be made fully watertight. Sadly, the Mopetta never became popular and only 14 were ever made.

Supercars

Marcello Gandini designed the Miura before he turned **28**.



Some cars are just too hot to handle. These high-performance sports cars, known as supercars, are phenomenally fast and often very expensive. Hand-crafted in small numbers, they offer the last word in speed and handling.

The first supercar emerged in the 1960s. High-performance cars such as the **Lamborghini Miura** had sleek lines, powerful engines, and were built low to the ground. Miura's successor, the **Countach, LP 400**, was just 3 ft 7 in (1.1 m) tall. Some supercars were made of high-tech

Inset rear wing *rises automatically to help car grip the road*

Pop-up headlights *in the nose*

Ferrari Enzo Italy 2002

226 mph (363 km/h)

Scissor doors *open upward and forward*

Mercedes-McLaren SLR 722S UK 2003

209 mph (336 km/h)

Twin exhaust pipes *mounted in the middle of the car*

205 mph (330 km/h)

Caparo T1 UK 2007

Koenigsegg CCX-R Sweden 2006

250 mph (402 km/h)

Wheels *made of carbon fiber save 11 lb (5 kg) weight per wheel*

Noble M600 UK 2009

225 mph (362 km/h)

Air inlet *channels air into the engine compartment*

Porsche 918 RSR Spyder Germany 2011

211 mph (340 km/h)

A Venom GT reached a top speed of 270 mph (435 km/h) in a test run.

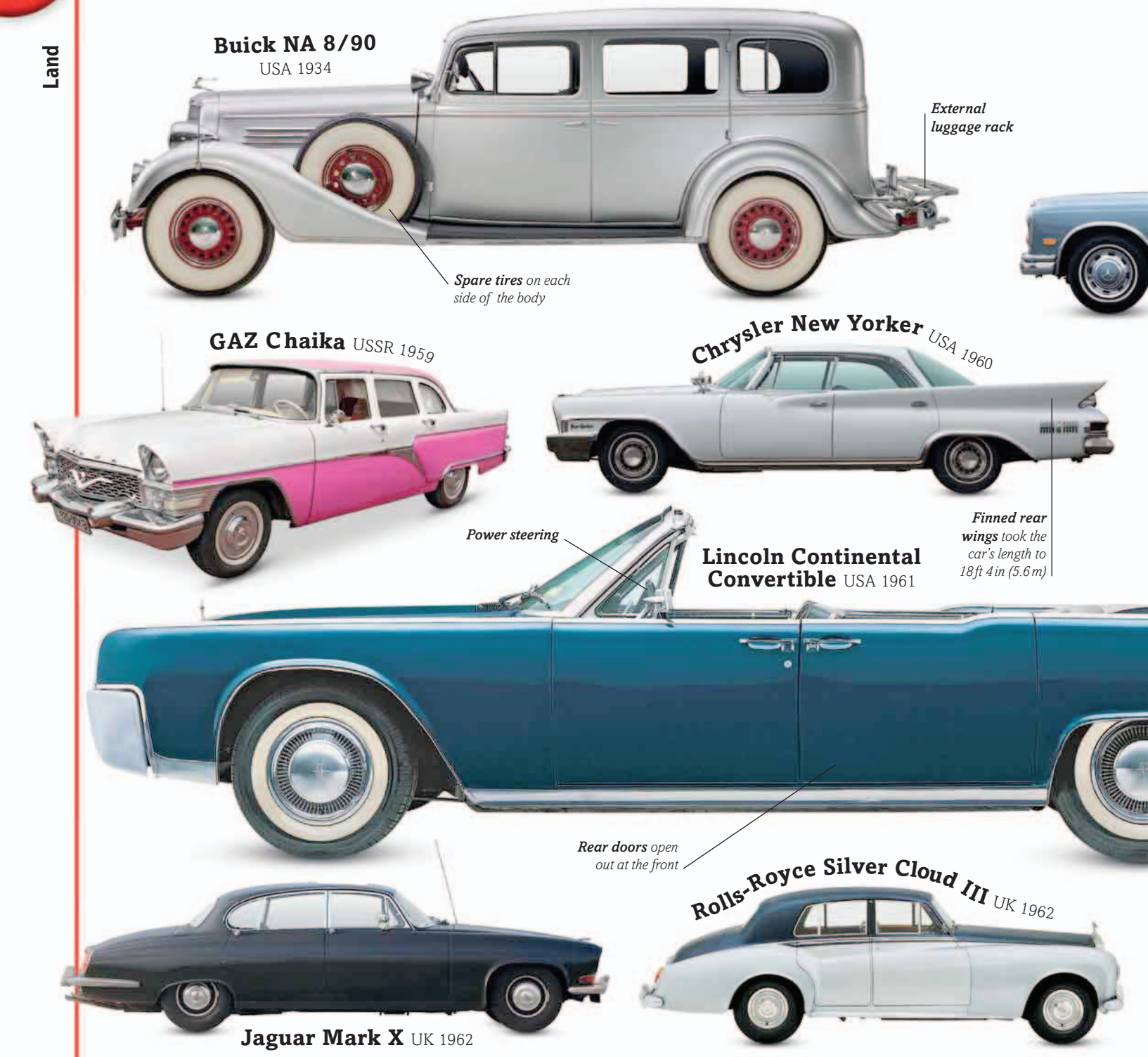
270 mph (435 km/h)

Hennessey Venom GT

USA 2014

material to keep their weight down, with the 1,036 lb (470 kg) **Caparo T1** being the lightest. The heavier supercars compensate with incredibly powerful engines. The **Hennessey Venom GT** can deliver up to 1,244 horsepower, which is 10 times the power of a hatchback. The **Noble M600's** twin turbochargers give it a top speed of 225 mph (362 km/h), while the **McLaren F1 LM** can hit 230 mph (370 km/h). Some supercars feature the latest in race car technology, like the **Mercedes-McLaren SLR 722S**, which has fly-by-wire (electronic) brakes.

Luxury rides



The last word in comfort, luxury cars are often packed with the most advanced driving and passenger features. These grand, superexpensive cars offer a quiet, cushioned ride for the rich, the powerful, and the famous.

Celebrities and dignitaries did not have to shut the doors of the **Mercedes-Benz 600**. This 2.9-ton car did it for them! Owners ranged from the Pope and presidents of many countries to the rock 'n' roll legend Elvis Presley. In the Soviet Union, the 18ft-4in- (5.6m-) long, seven-seater

Checker Marathon USA 1963

A rugged taxi, *but stretched for style*

Mercedes-Benz 600 Germany 1963

Gas tank with 12 gal (45 liter) capacity *fitted inside each rear wing*

Daimler DS420 UK 1968

Car accelerates from 0–60 mph (0–100 km/h) in under 7 seconds

Bentley Continental R UK 1991

Rolls-Royce Phantom Drophead UK 2007

Fold-up roof *stored in rear of car*

The Phantom Drophead was available in **4,300** different **colors**.

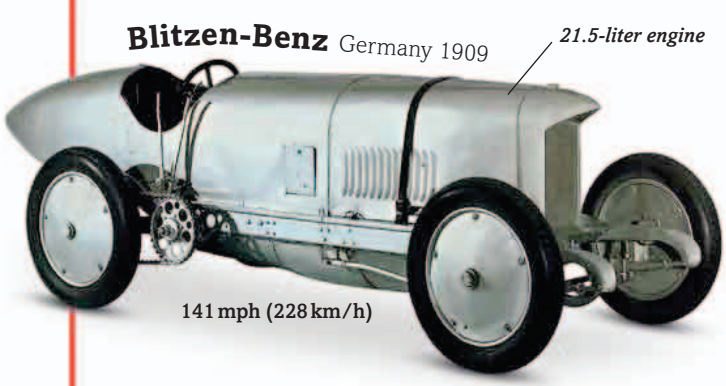
Cadillac STS V8 USA 2009

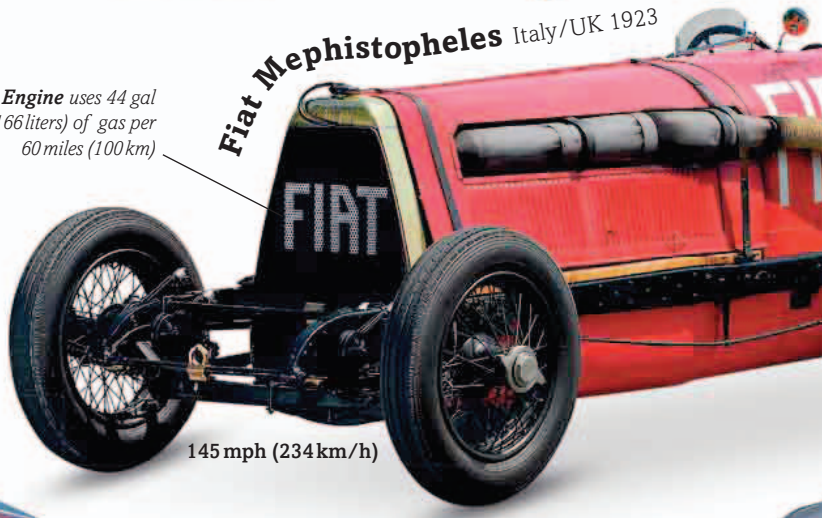
Sensors *alert the driver if the car drifts out of its lane*

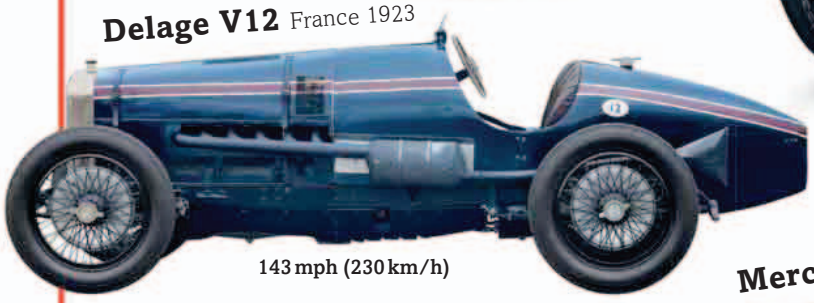
GAZ Chaika was the choice car for politicians, while the stately **Daimler DS420** was used by the British, Swedish, and Danish royal families. The car was based on the **Jaguar Mark X**, which came with a wood-paneled interior, plenty of legroom, and fold-down picnic tables. Some **Rolls Royce Silver Cloud IIIs** had cocktail bars and televisions, while the **Lincoln Continental Convertible** turned heads with its convertible, four-door design. The statue on the hood of the **Rolls-Royce Phantom Drophead** sinks into the hood when the car is locked up.

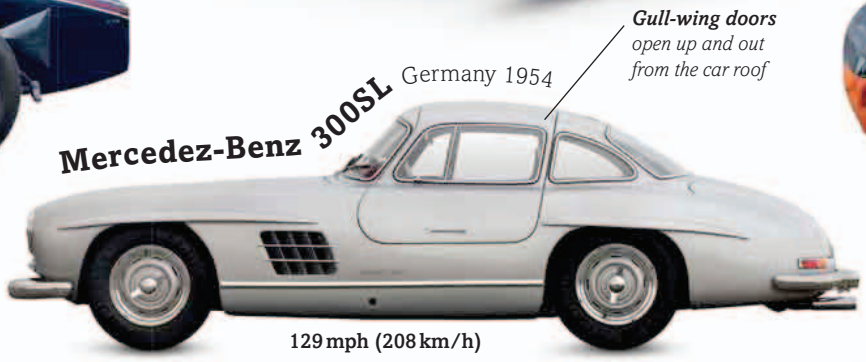
Record breakers

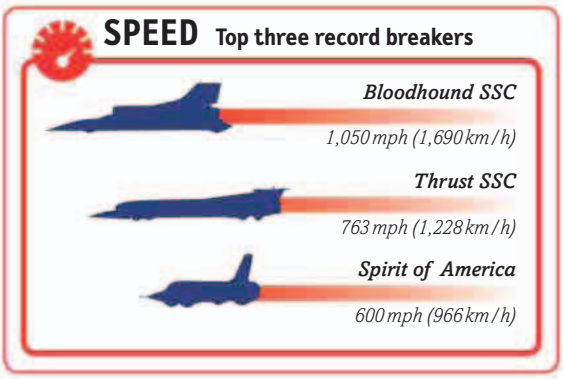
This car is made up of a Fiat SB4 and parts of a **London Bus**.











Cars have always been valued for their speed. Some people have built one-of-a-kind fast cars in an attempt to break land-speed records, while car manufacturers have competed to produce the fastest production cars.

The **Blitzen-Benz** was the first car with an internal combustion engine to break the 125 mph (200 km/h) barrier. In 1924, the **Delage V12** held the land-speed record for six days before it was broken by the **Fiat Mephistopheles** with a bomber aircraft engine. The **Bluebird CN7**, also

with an aircraft engine, was the last record-breaking car with wheels driven directly by the engine. Record breakers since then, such as the current holder **Thrust SSC**, are propelled by jet engines. The **Bloodhound SSC** team is hoping that their machine, using a Jaguar car engine, a jet engine, and a rocket engine, will set a new record at supersonic speeds. The **Mercedes-Benz 300SL** set a record for fastest production car in 1955, which was broken by the **Ferrari 365 GTB/4**. The **Bugatti Veyron Super Sport** is the current fastest production car.

DRAGSTER BURNOUT

Vrrrm, Vrrrm! Dave Gibbons revs up his Rough Diamond T dragster at the UK's Santa Pod Raceway in 2014. These mean machines race along straight pieces of tarmac track, known as drag strips, in high-speed races that last as little as five or six seconds. Blink and you'll miss the contests between these epic racers—the fastest-accelerating cars in the world.

Dragsters feature ridiculously powerful engines that burn an explosive fuel mixture. The most powerful, found in a class of dragster called Top Fuel, can generate a staggering 8,000 horsepower. That's more than the power created by all of the first 10 NASCARs or Formula One cars on a starting grid put together. This phenomenal force carries dragsters from 0–100 mph (0–160 km/h) in less than 0.8 seconds. After two or three seconds, they're rocketing along at more than 250 mph (400 km/h) while the fastest can cross the line at 310 mph (500 km/h). Dragsters need plenty of braking assistance, usually provided by large parachutes that open out behind the car to generate drag and slow it down.

Truck

Trucks come in many shapes and sizes. Articulated trucks come in two parts. At the front is a tractor, containing the engine and driver's cab. It is connected to the cargo-trailer by a pivoting joint, which allows the truck to go around tight corners. The **Kenworth C540** is a powerful long-distance truck that can haul a fully loaded trailer over long distances.

Sleeper cab › This cab contains a bed, storage space, and, often, cooking facilities for long-distance truckers.

Semitrailer › This is called a semitrailer, because it does not have a front set of wheels. It is designed to hook up to the tractor. This model is a curtain-sider, with fabric side panels that can be pulled aside for loading or unloading.

Wheels › Two sets of tractor rear wheels support the weight of the trailer.


Cab light
Exhaust stack ›
Vertical exhaust pipes release waste gases from the engine.
Windshield
Rearview mirror
Radiator grille ›
The grille lets in air to cool the large diesel engine that powers the truck.
KENWORTH
BE-16-88
Steps to driver's cab
Fender
Bumper

Tons of trucks

Thornycroft Type J UK 1917

Solid-rubber tires

Stack from steam engine

Flatbed to carry sacks, boxes, or other loads

Wallis & Steevens Wagon 7279 UK 1912

During World War I, some Type Js were fitted with **guns** to shoot at enemy aircraft.

Two-doored cab seats only one

Piaggio Ape Model D Italy 1967

Frame for protective cover

Subaru Sambar Kei truck Japan 1969

Tree logs carried in trailer from forest to lumber mill

Chevrolet C10 USA 1960s

Driver's cab contains sleeping bunk in roof

Renault TR 280 France 1971

There are almost as many types of trucks as there are jobs they perform—from whisking packages around town to hauling farm animals, cars, or goods on trailers. The first motorized trucks ran on steam power, but today most have diesel engines.

In Japan, tiny Kei trucks, such as the **Subaru Sambar,** carry small cargos around cities, while in Italy, the even smaller **Piaggio Ape Model D** runs on three wheels, with a motorcycle engine powering its rear wheels. Pickup trucks, such as the **Chevrolet C10**,

MCD DAF 85 Netherlands 1992

Mercedes-Benz 1838 tanker truck Germany 1996

Rear supported by three sets of wheels

DAF XF105 Netherlands 2008

Racing
DAF 85 trucks reach speeds of up to **100 mph** (160 km/h) on race tracks.

Large 793-cu in (13-liter) engine situated below driver's cab

Vertical exhaust

Radiator grille

Scania P400 Sweden 2009

Volvo Bobtail semi-truck Sweden 2011

Living quarters contain bed for driver

are often just a little larger than a sedan, and have an open cargo bed behind the driver's cab. Many large trucks, such as the **Volvo Bobtail** and **Scania P400**, are designed to haul a range of trailers carrying very different loads. These trucks have a tractor unit with a driver's cab and an engine, and are articulated, which allows the truck to turn around tight corners. Trailers can be box-shaped, open, or specialized, such as the ramped car transporter hauled by the **MCD DAF 85**, or a tanker containing liquid pulled by the **Mercedes-Benz 1838.**

Special task trucks

Alvis Stalwart UK 1966

Three-seater cab *can be entered from the roof*

Underside of vehicle *is waterproof to travel through water*

Douglas P3 UK 1970

Walter Snowfighter USA 1972

Large blades *push snow to the sides*

Water-and-foam cannon *can fire hundreds of liters of liquid per minute*

Gloster Saro Javelin UK 1987

Telescopic ladder *can extend upward to reach into multistory buildings*

Six-wheel drive *with engine powering all wheels*

American La France Metrostik 75 USA 2000

Extended cab *carries firefighters and equipment*

Outrigger *provides stable base when ladder is extended*

Large hopper *to collect garbage*

While some trucks are designed to be versatile and carry a wide range of loads, others are designed and specially built to do one job and do it extremely well. Meet some of the more extraordinary special task trucks.

Every airport has tugs, such as the **Douglas P3**, which can pull a giant aircraft into position, and crash tenders such as the **Gloster Saro Javelin**. These high-speed firefighting vehicles often have four-, six-, or eight-wheel drive and can rush to a stricken aircraft to cover it in water and foam.

Powerful crane *can lift smaller tow trucks*

Kenworth W900 tow truck
Australia 2007

Flashing warning lights

Mercedes-Benz Citaro ambulance Germany 2009

Citaro is the largest civilian ambulance, with space for 20 patients.

Driver's cab windows *are protected from branches and debris by metal mesh*

John Deere 843K USA 2010

Giant tires *support weight of the 27,990-lb (12,696-kg) vehicle and its load*

Holder C270 Germany 2010

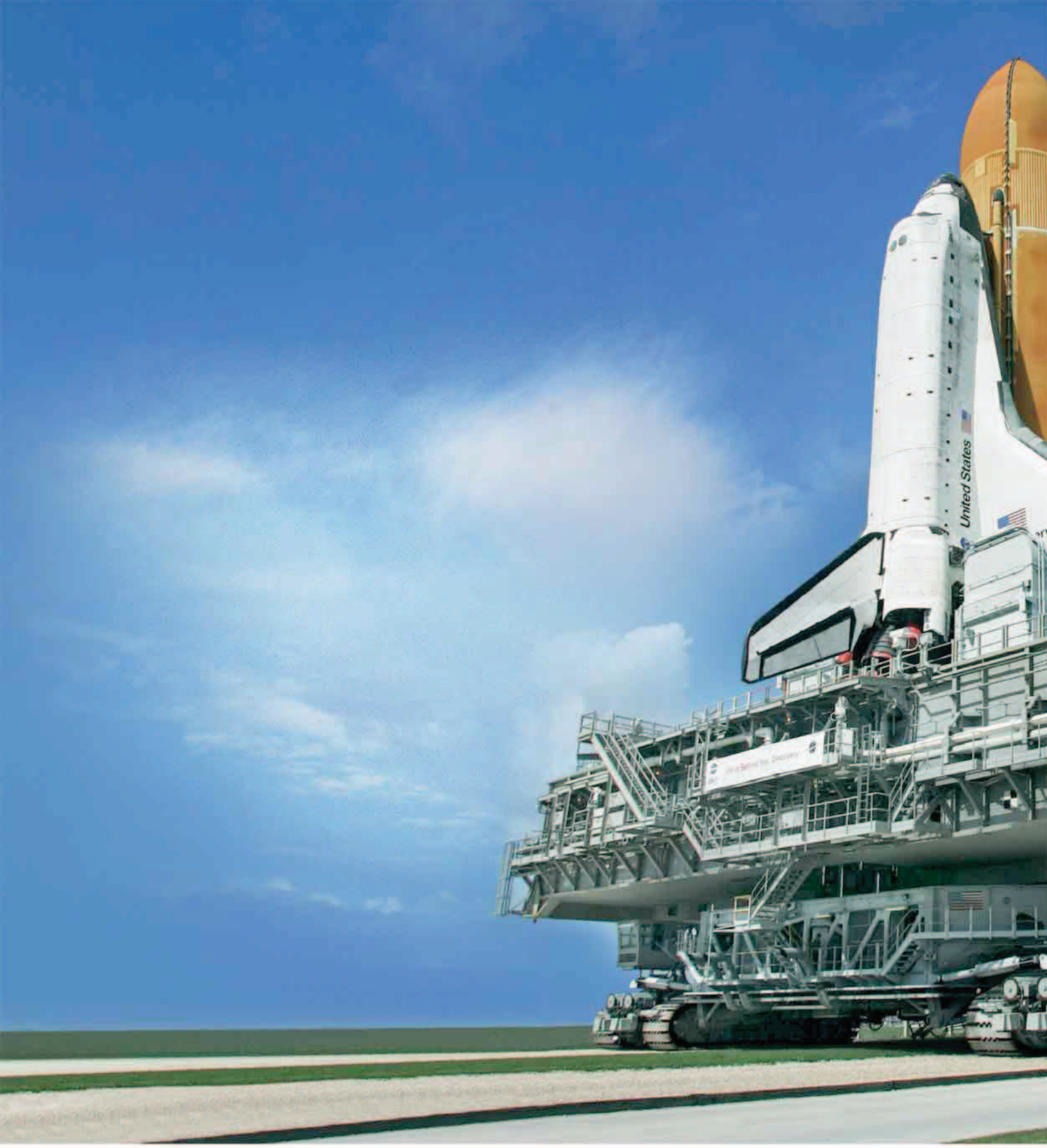
Rapidly spinning brushes *remove dirt*

Vertical exhaust pipe

Autocar E3 refuse truck USA 2011

Hyundai 700S-7E South Korea 2012

Special purpose trucks are also found every day on city streets. Street sweepers, such as the small **Holder C270**, can turn their cabs to sweep around tight corners, while garbage trucks, such as the **Autocar E3**, collect and compact garbage in their rear hoppers before taking it to dumps or recycling centers. The **Walter Snowfighter** can clear roads of snow, and the **Kenworth W900** lifts and recovers broken-down vehicles. Out in the countryside, tree fellers such as the **John Deere 843K** use powerful saws and grippers to fell and remove trees.

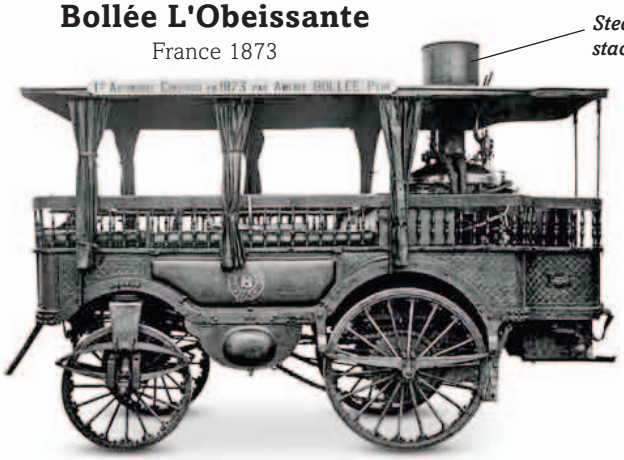


SHUTTLE CRAWLER Meet the ultimate heavy hauler—NASA's gigantic Crawler Transporter. This picture shows it inching the Space Shuttle Discovery from the Vehicle Assembly Building to Launchpad 39B at the Kennedy Space Center in Florida in 2005. Fully loaded, the Shuttle spacecraft weighs more than 2,500 tons (2 million kg), so it takes a serious machine to carry such an extreme load.

NASA's two Crawler Transporters, nicknamed Hans and Franz, were built in the 1960s to carry Saturn V launch vehicles. The loading platform is 295 sq ft (27.4 sq m)—about the same size as a baseball diamond. Each Crawler Transporter is 131 ft (40 m) long, 115 ft (35 m) wide, and weighs 3,000 tons (2,721,000 kg). When loaded with a space vehicle, the crawlers move along a special, heavy-duty road, known as a crawlerway, at a top speed of 1 mph (1.6 km/h). The vehicle is powered by 16 electric engines, and the electricity is supplied by an onboard generator run by two diesel engines. Burning fuel at 126 gal per mile (297 liters per km), the Crawler Transporter is a real gas-guzzler.

Bus stop

Bollée L'Obeissante
France 1873



LCOG B-type
UK 1911

AEC Routemaster UK 1954

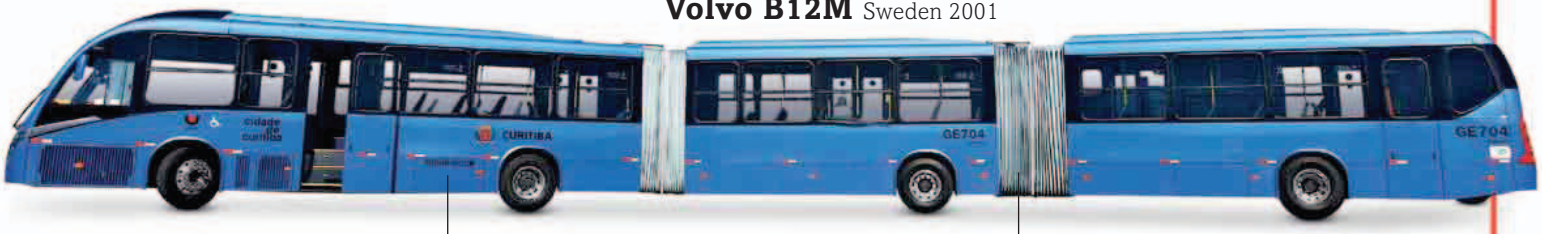
Foremost Terra bus
Canada 1986

Volvo B10MA *Bendy Bus* Sweden 1996

The first motorized buses were steam-powered and carried people for short distances in the 19th century. The arrival of the internal combustion engine led to bigger and more powerful buses for commuters, tourists, and school runs.

Driven by twin steam engines, one for each rear wheel, the **Bollée L'Obeissante** could carry 12 passengers at speeds up to 25 mph (40 km/h). Gradually, gasoline-engine buses took over the first mass-produced bus, the **LCOG B-type**, had seats for 16 passengers inside and 18 on the

Volvo B12M Sweden 2001



Underfloor-mounted engine

Joint covered by flexible rubber seals

The bendy, 92-ft- (28-m-) long B12M can seat up to **270 passengers**.

School bus USA 2002

Rails for a flexible roof

High-mounted driver's cab

Roma Cristiana open bus Italy 2003

49 ft 2 in (15 m) long

Wi-fi onboard for using gadgets

Fold-down steps

Van Hool sleeper bus Belgium 2009

top deck. Double-decker buses proved popular, with room for many more people. The **AEC Routemaster** became a British icon, carrying up to 64 passengers around London, UK, while today's open-topped buses, such as the **Roma Cristiana**, give tourists spectacular city views.

The rugged, single-decker **Foremost Terra Bus** transports tourists and workers around ice-bound regions in Canada and Antarctica. The **Volvo B10MA** can bend in the middle to travel around corners, while the **Van Hool sleeper bus's** seats convert into 42 beds for long, overnight journeys.

Tractor

Tractors are a farm's workhorses, used to pull plows and other tools in fields, or to carry and lift a range of loads. These machines vary in size, from tiny tractors used in gardens and parks to giant beasts with massive pulling power. The **Massey Ferguson 7618** is a versatile, large tractor that can perform lots of different jobs in the field.

Engine › A large engine burns diesel fuel. This tractor has a top speed of around 31 mph (50 km/h) on the road and 17 mph (28 km/h) on the field.

Engine hood

Vertical exhaust

Radiator grille

Mudguard

Weight frame › Weights can be added to the front of the tractor to balance out the weight of the tools or loads it carries behind it.

Fuel tank

Tire tread › Deep tread on the rubber tire helps the tractor grip the soft ground and move forward or backward.

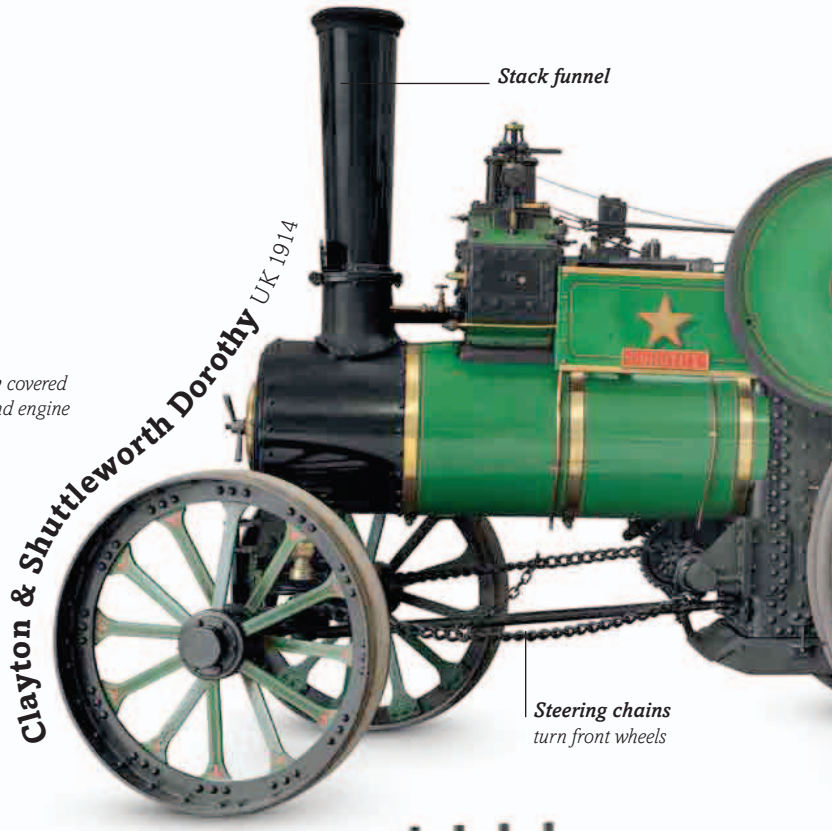
Cab light › Equipped on all the four corners of the cab, these light up the area around the tractor.

Rear wheel › Huge rear wheels equipped with giant tires, 5 ft 1 in (1.8 m) in diameter and 22¾ in (58 cm) wide, support the tractor's weight.

Total tractor

Twin City 40-65
UK 1916

Canopy *covered driver and engine*



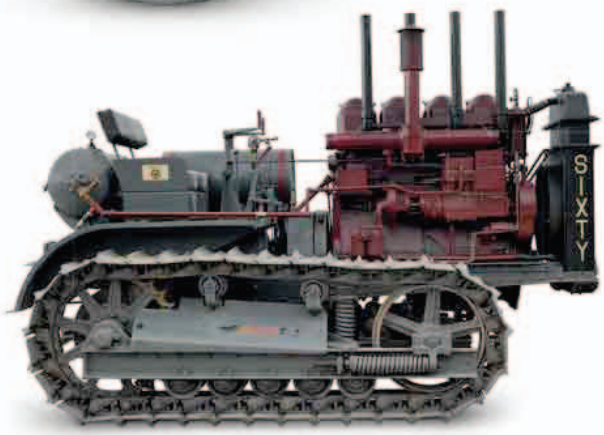
Clayton & Shuttleworth Dorothy UK 1914

Stack funnel

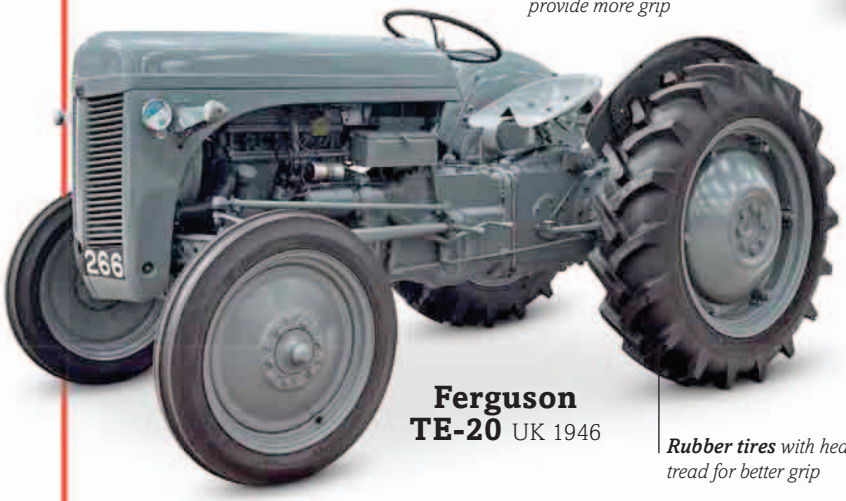
Steering chains *turn front wheels*

Waterloo Boy
USA 1917

Steel wheels *equipped with blades dig into the ground to provide more grip*

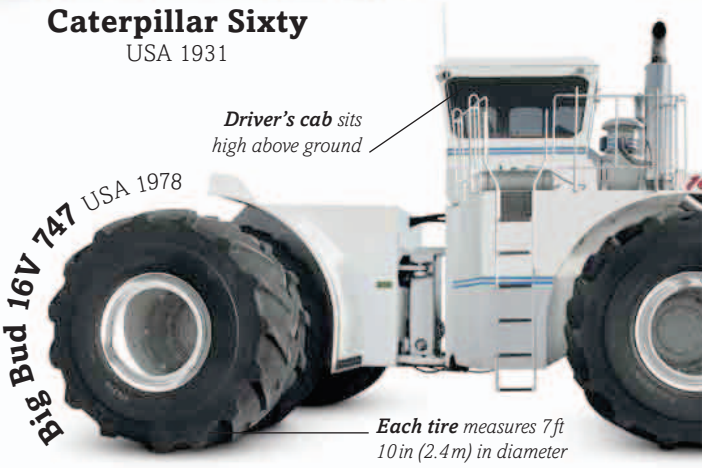


Caterpillar Sixty
USA 1931



Ferguson TE-20 UK 1946

Rubber tires *with heavy tread for better grip*



Big Bud 16V 747 USA 1978

Driver's cab *sits high above ground*

Each tire *measures 7 ft 10 in (2.4 m) in diameter*

Powered by steam, the first farm tractors were often heavy and slow, but they could pull objects with great force. Over time, diesel and gas engines replaced steam, while solid steel wheels made way for tracks and wide rubber tires.

The **Clayton & Shuttleworth Dorothy** steam-powered tractor weighed 22,046 lb (10,000 kg) and had a top speed of 5 mph (8 km/h). In contrast, the 15,212-lb (6,900-kg) **JCB Fastrac 185-65** can reach 50 mph (80 km/h). The **Ferguson TE-20** became so

popular that over half a million were built. Some tractors run on a continuous belt called a track, which spreads weight evenly over the ground, giving good stability and grip. The **Caterpillar Sixty** had steel tracks, while the modern **Challenger MTF 7650** has rubber tracks.

Tractors today range greatly in size. The small **Massey Ferguson 1540** is used in parks and gardening, while the **New Holland T9.505** is so long that its body is hinged in the middle. At 27 ft (8.23 m) long, the **Big Bud 16V 747** was used on large American cotton farms.

On the farm

This harvester can pick and wash as many as **one million** pumpkins in a week!

Massey Ferguson 9240 UK 1995

***Sharp metal discs** of **the harrow** break up soil*

***Tank** provides water to wash pumpkins*

Pumpkin Harvester UK 2006

***Large, chunky tire** provides grip over rough and muddy ground*

***Folding crop-spray boom** can stretch out to a width of almost 60 ft (18 m)*

***Forks** can lift up to 7,716 lb (3,500 kg)*

Steps to driver's cab

John Deere 5430i USA 2008

Catterpillar TH406 USA 2010

***Reel** gathers in stalks of cereal crops toward cutting bar*

***Cutting head** cuts grass and stalked crops*

***Cutting bar** slices the stalks off the plant*

John Deere W260 USA 2013

John Deere S690 USA 2013

Farming involves a vast amount of hard work but, fortunately, machines have come to the rescue. Farm machines automate and speed up many tasks, which previously had to be done by hand or by using animals.

Some farm tools like plows and disk harrows can be pulled or operated by multipurpose tractors such as the **Massey Ferguson 9240**. Growing crops are protected by crop-dusting machines, such as the **John Deere 5430i**, whose giant booms spray large areas of fields

New Holland T6.140
USA 2013

Hydraulic-powered grippers *can hold and lift hay bales*

New Holland 740TL *USA 2013*

Unloading pipe *discharges 35.7 gal (135 liters) of grain per minute*

Driver's cab

New Holland Braud 960L USA 2013

Grain tank *can hold up to 3,725 gal (14,100 liters) of grain*

Cutter head *removes flowers from top of corn plant*

Narrow wheels *fit into gaps between rows of corn crops*

Hagie 204SP Detassler USA 2013

with pest-removing chemicals. Come harvest time, different machines speed up the collection of crops, such as the **New Holland Braud 960L**, which travels above rows of vines, harvesting grapes, or the **Pumpkin Harvester**, which picks, washes, and packs pumpkins. Large combine harvesters, such as the **John Deere S690**, cut the stalks of cereal crops, separate the grain, and shoot the remaining straw out the back. This straw is packed into hay bales that can be lifted by forklifts, such as the **Caterpillar TH406**, or held by grippers, as on the **New Holland 740TL**.

MONSTER LEAP

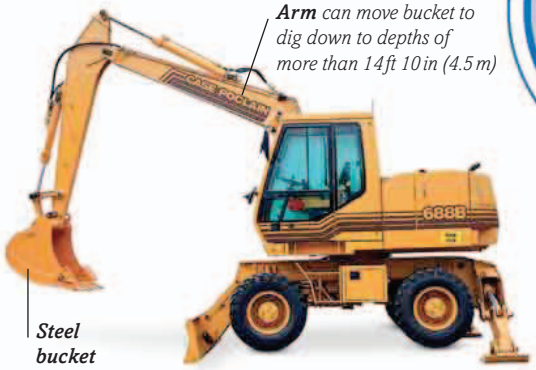
At the Monster Mania festival in the UK, Ian Batey flies high in his ***Lil' Devil*** monster truck over a row of old cars. Fueled by high octane racing methanol in its hefty V8 engine, this powerful vehicle boasts ten times as much power as a regular family car. It weighs more than 8,800 lb (4,000 kg)—guaranteeing a crushing ending for any of the wrecked cars should it land on them.

Ever since Bob Chandler built the original Bigfoot monster truck in 1979 in the USA, these mean machines have been entertaining crowds all over the world with their antics. Events include races over dirt courses in arenas as well as stunts, jumps off ramps, and plenty of car crushing. Many monster trucks begin life as a humble pickup, a Chevrolet Silverado in the case of *Lil' Devil*. Only the body is kept, as the vehicle is tricked out with a tubular steel frame chassis and mighty 5-ft-7-in- (1.7-m-) high "terra" tires. These ride on suspension systems capable of absorbing enormous impacts on landing while the driver, held firmly in his seat in a racing harness, focuses on pulling amazing monster truck moves.

Construction and mining

Front roller *can be moved left or right to turn the vehicle*

Hamm HW90/10 Germany 1987



Arm *can move bucket to dig down to depths of more than 14 ft 10 in (4.5 m)*

Steel bucket

Case Poclain 688B USA 1993

The **hopper** can hold **90 tons** of rock—as heavy as **20** monster trucks.

Hopper *can be tipped by hydraulic arms*

Tire *is 8 ft 11 in (2.7 m) tall and weighs more than 3,307 lb (1,500 kg)*

Vertical exhaust pipe

Steel loader *can lift more than 2,200 lb (1,000 kg) in a single scoop*

Caterpillar 950G USA 1998

BELAZ-75570

31 ft 10 in (9.7 m) tall

Liebherr LTM1500 Germany 2000

Outriggers *stabilize the crane when it is raised*

Construction sites and mines have a lot of digging, leveling, and heavy lifting going on, and big, rugged machines do most of the work. They have to be strong to withstand the stresses of the tasks, and reliable to work all day long.

Excavators are digging machines usually fitted with a steel bucket that cuts into the earth. Some, such as the **Case Poclain 688B**, run on wheels, while others, such as the **John Deere 160DL C**, run on continuous tracks, which are ideal for crossing muddy ground. Front loaders, such as

Drum *mixes concrete for building purposes*

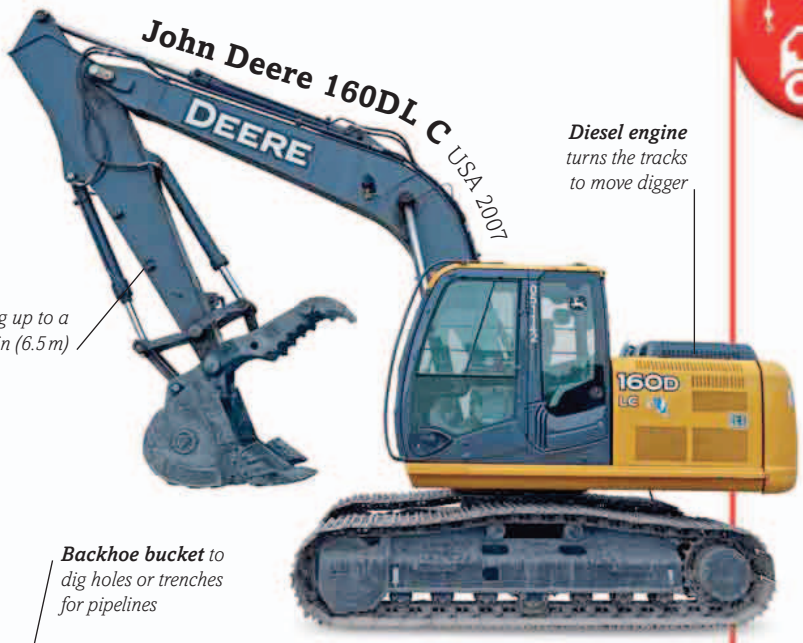
Mercedes-Benz Germany 2007

John Deere 160DL C USA 2007

Diesel engine *turns the tracks to move digger*

Excavator *can dig up to a depth of 21 ft 4 in (6.5 m)*

BelAZ-75570 Belarus 2008



Backhoe bucket *to dig holes or trenches for pipelines*

Front loader *can carry and push large amounts of soil and other materials*

JCB 3CX UK 2009

The **Dancing Diggers** are a team of JCBs that perform routines to music.

Long blade *levels materials for a smooth surface*

Caterpillar 12M2 USA 2011

John Deere 650K XLT USA 2012

the **Caterpillar 950G**, feature a large front-scoop, and backhoe loaders, such as the **JCB 3CX**, have both a front-loader and a rear bucket-digger. The **John Deere 650K XLT** is a bulldozer equipped with a long, strong blade to push materials along the ground, while compactors, such as the **Hamm HW90/10**, use heavy rollers to press down and make a firm surface. Giant cranes lift materials when building tall structures and some, such as the **Liebherr LTM1500**, are mobile, with an arm that telescopes out and up to a distance of 276 ft (84 m)—longer than a Boeing 747 jumbo jet.

Tanks and tracks

Stabilizer *prevents tank from tipping over backward*

Renault FT-17 France 1917

Turret hatch*, below which tank commander sits*

Mark V UK 1918

Gun *originally used in ships and coastal forts*

Continuous metal tracks *around side of body*

Panzerkampfwagen IV Germany 1936

M4A1 Sherman USA 1941

Turret *holds three of the five crew members*

T-34/85
Soviet Union 1941

Large gun *can fire shells more than 3 miles (5 km)*

Tough armor *made of ceramics and metals*

CHALLENGER 1 MBT

9 ft 8 in (3 m) tall

Tanks are heavily armored vehicles that run on tracks so they can cross muddy ground and other difficult terrain. They are usually equipped with a powerful, shell-firing artillery gun. The first tanks saw service in World War I.

The **Mark V** had an eight-man crew and a top speed of 5 mph (8 km/h), the same as the two-man **Renault FT-17**—the first tank with a rotating gun turret. The **Panzerkampfwagen IV's** powerful gun could pierce the armor of other tanks. It had a top speed of 24 mph

M4 Sherman V *Crab* USA 1943

Heavy, spinning chains *pound the ground to set off land mines*

Amphibious landing craft

M-29C Weasel tank *transported inside*

Landing Vehicle Tracked Mk IV Buffalo USA 1943

With a top speed of 57 mph (92 km/h), this was the **fastest tank** of World War II.

M18 *Hellcat* USA 1944

16-ft- (4.9-m-) long aluminum body *holds a crew of three*

Alvis FV107 Scimitar UK 1971

Smoke-grenade launchers *generate smokescreen for defense*

Tracks *can travel through 6-ft- (1.8-m-) deep water*

FV104 Samaritan UK 1978

Challenger 1 MBT UK 1983

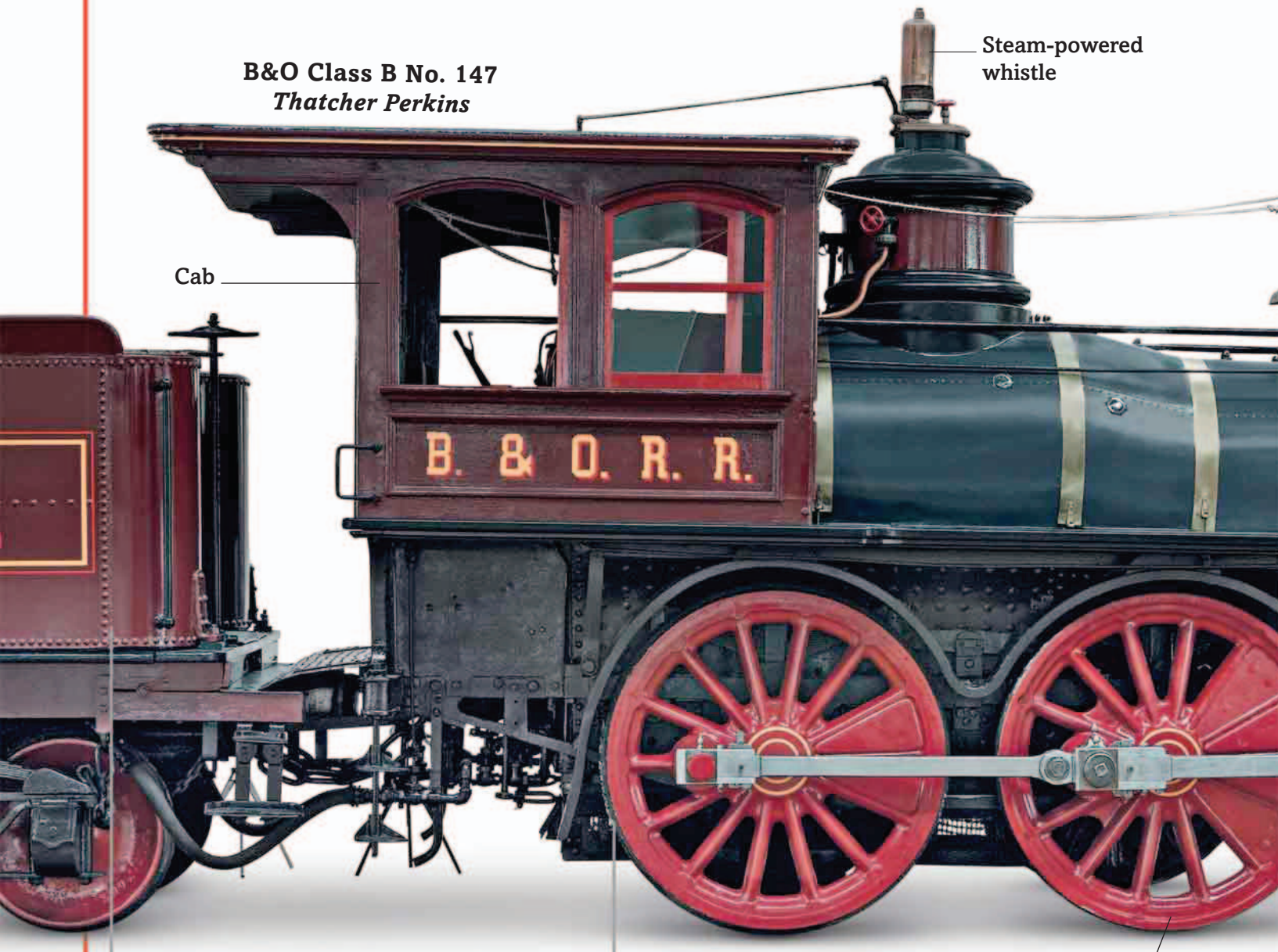
Leopard C2 Germany 2000

Armored skirt *protects upper tracks*

(39 km/h) and a range of 125 miles (200 km). The **T-34/85**, one of its opponents, could travel twice as far. Other military vehicles are also armored and tracked but perform different tasks. The **FV104 Samaritan** is a battlefield ambulance, carrying up to six patients on stretchers, while the **Sherman *Crab*** has flailing chains to clear paths through minefields. Main battle tanks, such as the 68-ton **Challenger 1 MBT**, are large and equipped with powerful weapons. In contrast, the **Alvis FV107 Scimitar** weighs less than 9 tons and can travel at 50 mph (80 km/h).

Steam train

Steam trains have engines that burn fuel in their firebox. The heat boils water to produce steam, which is fed into cylinders where it expands to drive the pistons. The movement of the pistons turns the wheels with the help of a rod and a crank, moving the train. This American locomotive from 1863, ***Thatcher Perkins***, weighs 45 tons and could haul several wagons or carriages at 50 mph (80 km/h).



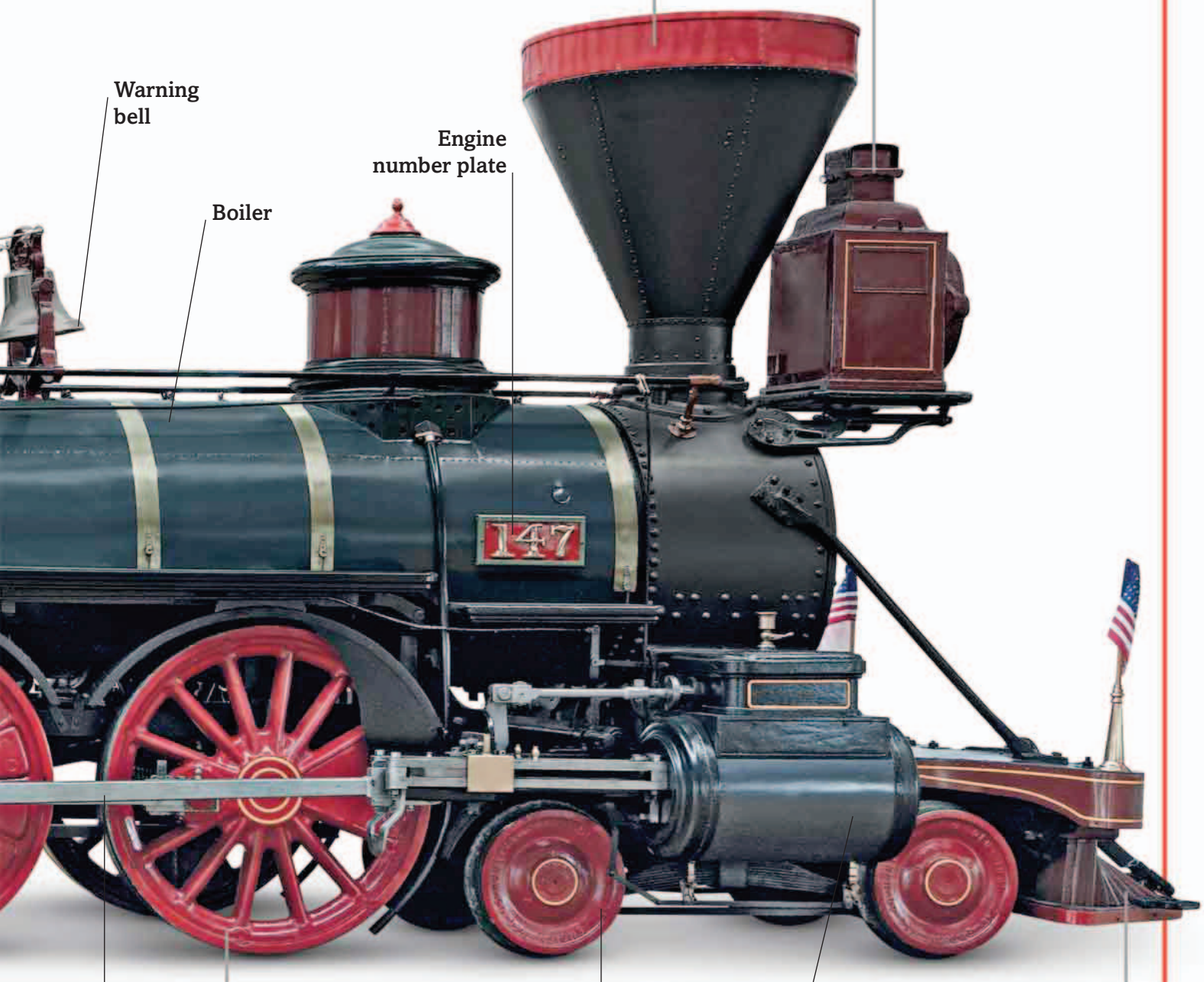
Tender › On many trains, this stored both water and fuel, often in the form of coal or, on this train, wood, to power the engine.

Wheel brakes › To slow down the train, the driver pulls a lever, which presses brake shoes directly onto the driving wheels.

Driving wheel

Stack › The smoke from the burning fuel in the firebox is channeled up and out through the stack. This one is fitted with layers of mesh to stop any dangerous sparks from escaping.

Headlamp › A large lamp burned oil to light up the tracks ahead.



Warning bell

Engine number plate

Boiler

Coupling rod

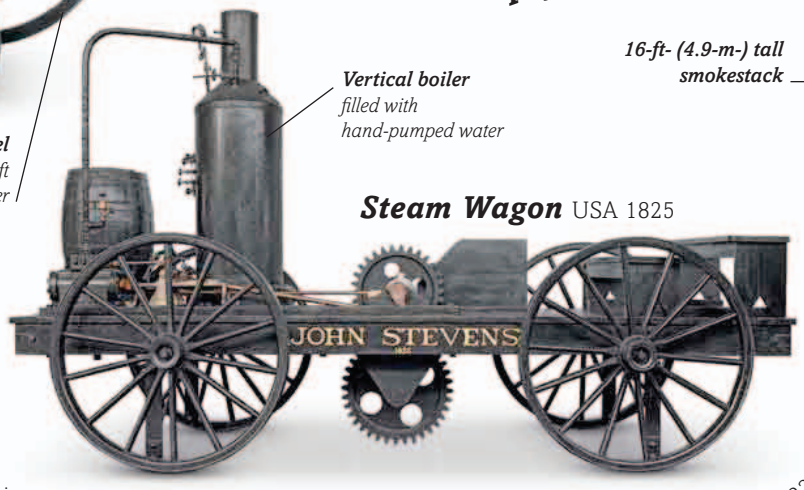
Wheel arrangement › Steam engines are defined by the number of wheels they have. This one has four leading wheels and six driving wheels.

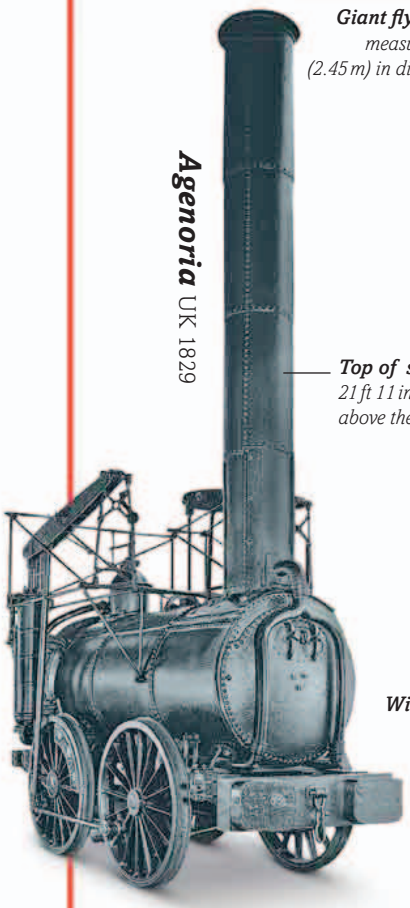
Leading wheel

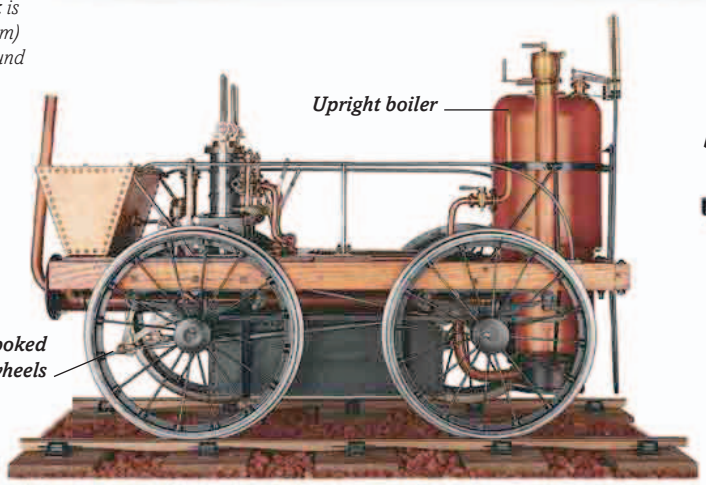
Engine cylinder

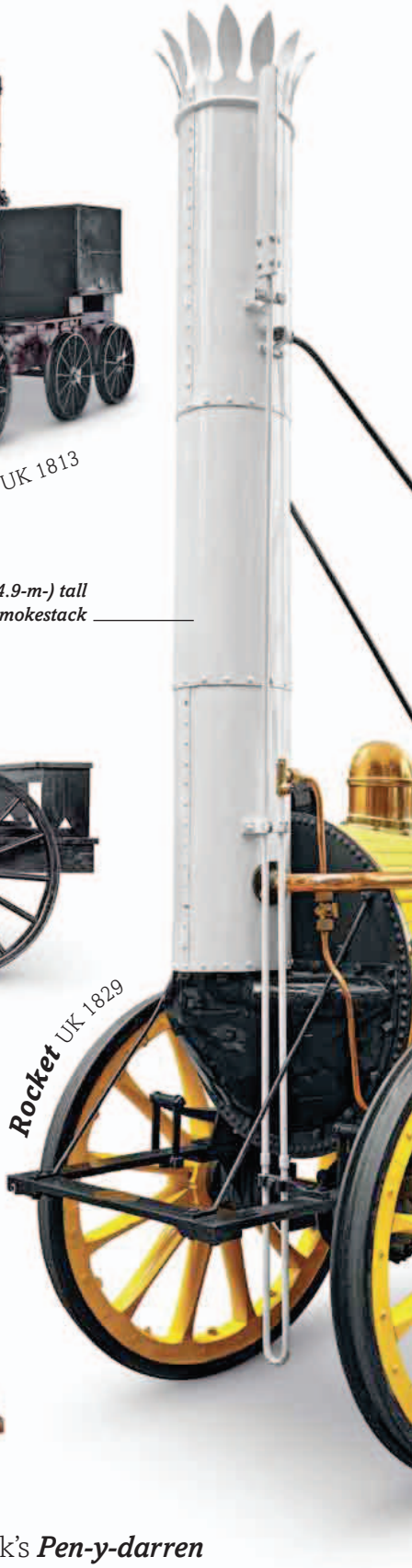
Pilot › Also known as the cowcatcher, this brushes aside obstacles, such as tree branches, from the train's path.

Early steam









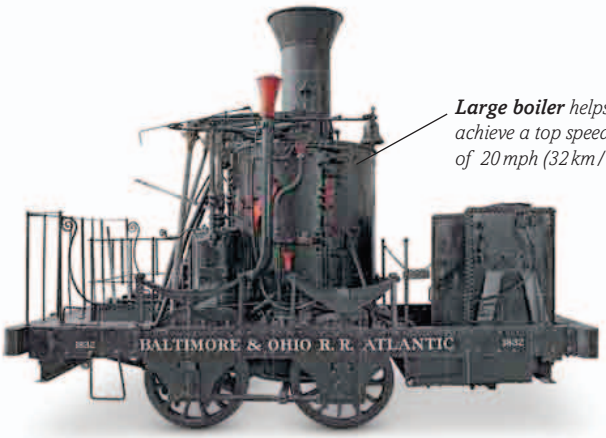
Novelty UK 1829

The first steam engines were used in factories to run machines, or in mines to pump out water. Richard Trevithick, a mining engineer, was one of the first to use steam to power a moving locomotive, sparking a transportation revolution.

In Wales in 1804, Trevithick's ***Pen-y-darren*** made the first railroad journey at less than 2 mph (4 km/h), hauling 12 tons of cargo and 70 people over 8.9 miles (14.4 km). Other steam engines, such as the ***Puffing Billy*** and ***Agenoria***, quickly followed, ferrying coal or goods from factories.

Tubes *inside boiler are made of gun barrels*

Tom Thumb
USA 1830

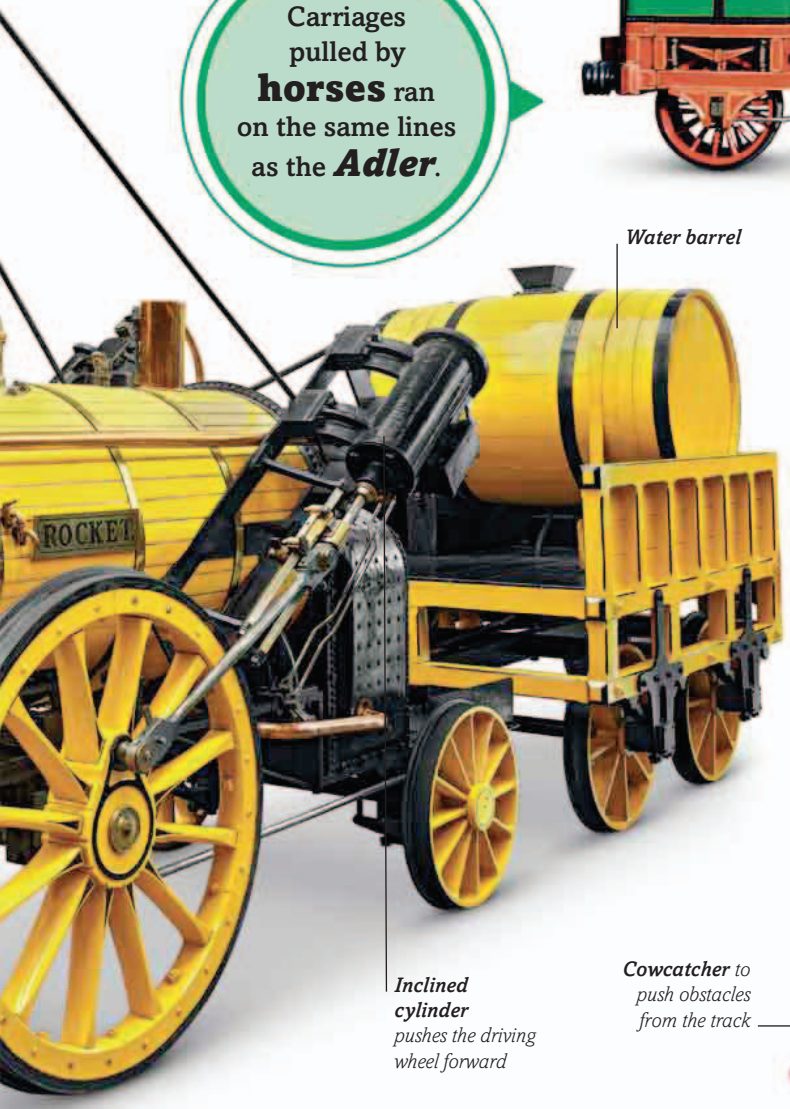


Large boiler *helps achieve a top speed of 20 mph (32 km/h)*

B&O Atlantic USA 1832

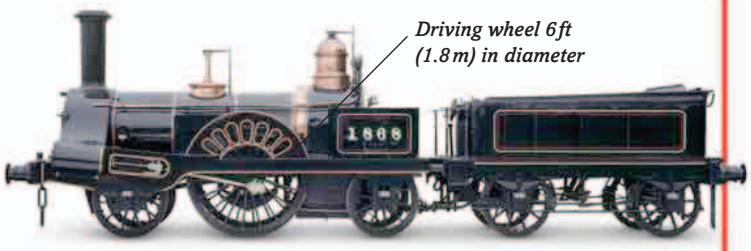
Carriages pulled by **horses** ran on the same lines as the ***Adler***.

Adler UK/Germany 1835



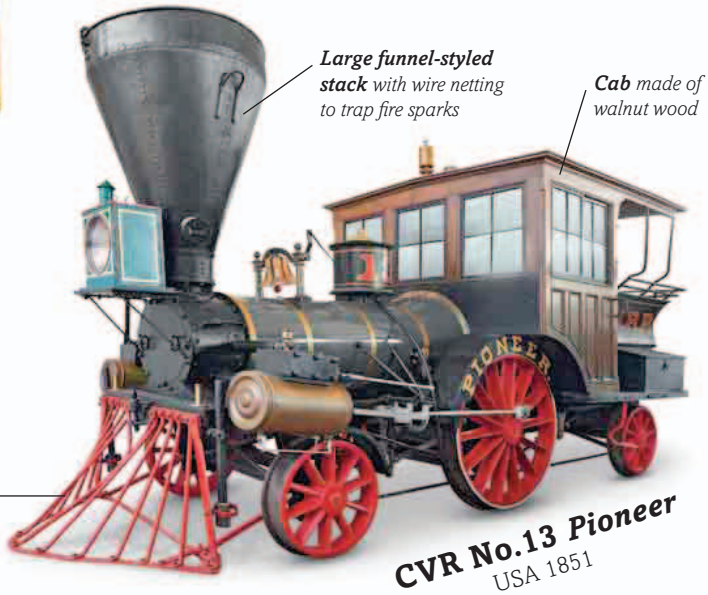
Water barrel

Inclined cylinder *pushes the driving wheel forward*



Driving wheel 6ft (1.8 m) in diameter

GJR *Columbine* UK 1845



Large funnel-styled stack *with wire netting to trap fire sparks*

Cab *made of walnut wood*

Cowcatcher *to push obstacles from the track*

CVR No.13 Pioneer
USA 1851

In 1829, Robert Stephenson's ***Rocket*** beat the ***Novelty*** at the Rainhill Trials in the UK, where engines competed to run on the Liverpool and Manchester Railway—the world's first intercity line. Stephenson's company later built the ***Adler***, the first German commercial train. John Steven's ***Steam Wagon*** was the first American train, but it ran on a small circular track. The first engine used on regular service in the USA was ***Tom Thumb*** on the Baltimore & Ohio Railroad (B&O). By 1840, the country had over 2,796 miles (4,500 km) of track, more than found in the whole of Europe.

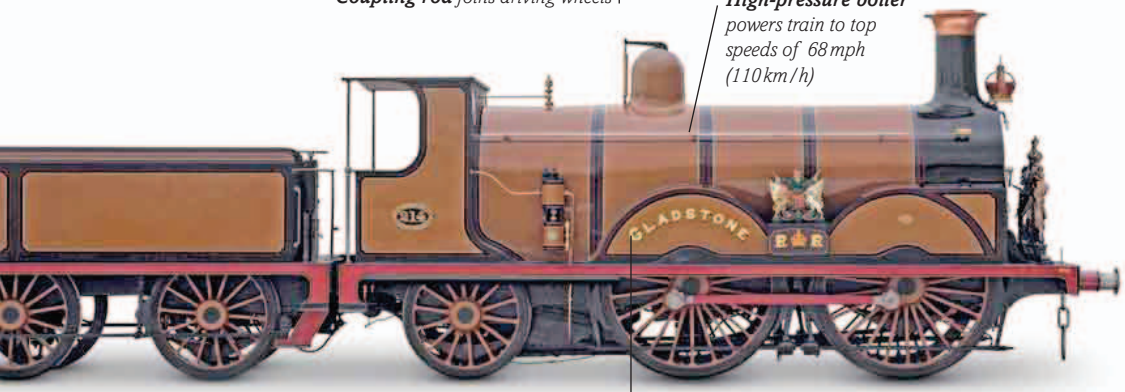
Mainstream steam

Fairy Queen was given **national treasure** status by India in 1972.

Steam railroads boomed in the later half of the 19th century, opening up new territories and connecting towns and cities. Locomotives developed rapidly, to become faster, more reliable, and able to pull more cars or cargo wagons.

The **SNB *Limmat*** ran on the first railroad line in Switzerland, while the **EIR No. 22 *Fairy Queen*** operated in India for 54 years. The **DHR Class B**, also from India, had a short wheelbase, which helped it grip the track of the Darjeeling Mountain Railway that rose 6,500 ft (2,000 m) in

Met Class A No. 23 UK 1864

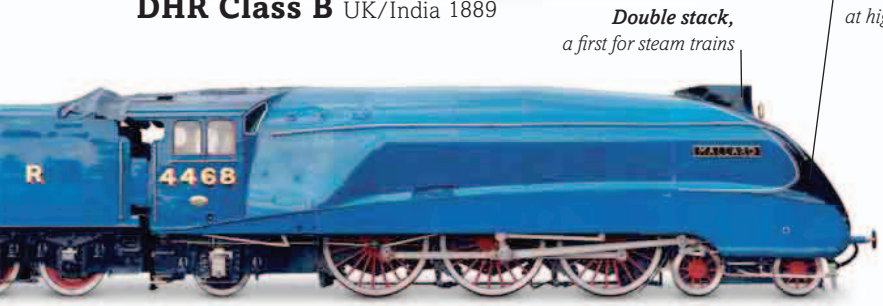


LB&SCR B1 Class UK 1882

After World War I, Germany gave **627** Class P8s to European nations as war damages.

DHR Class B UK/India 1889

Prussian Class P8 Germany 1908



Class A4 *Mallard* UK 1938

PP&L *D* Fireless Locomotive USA 1939

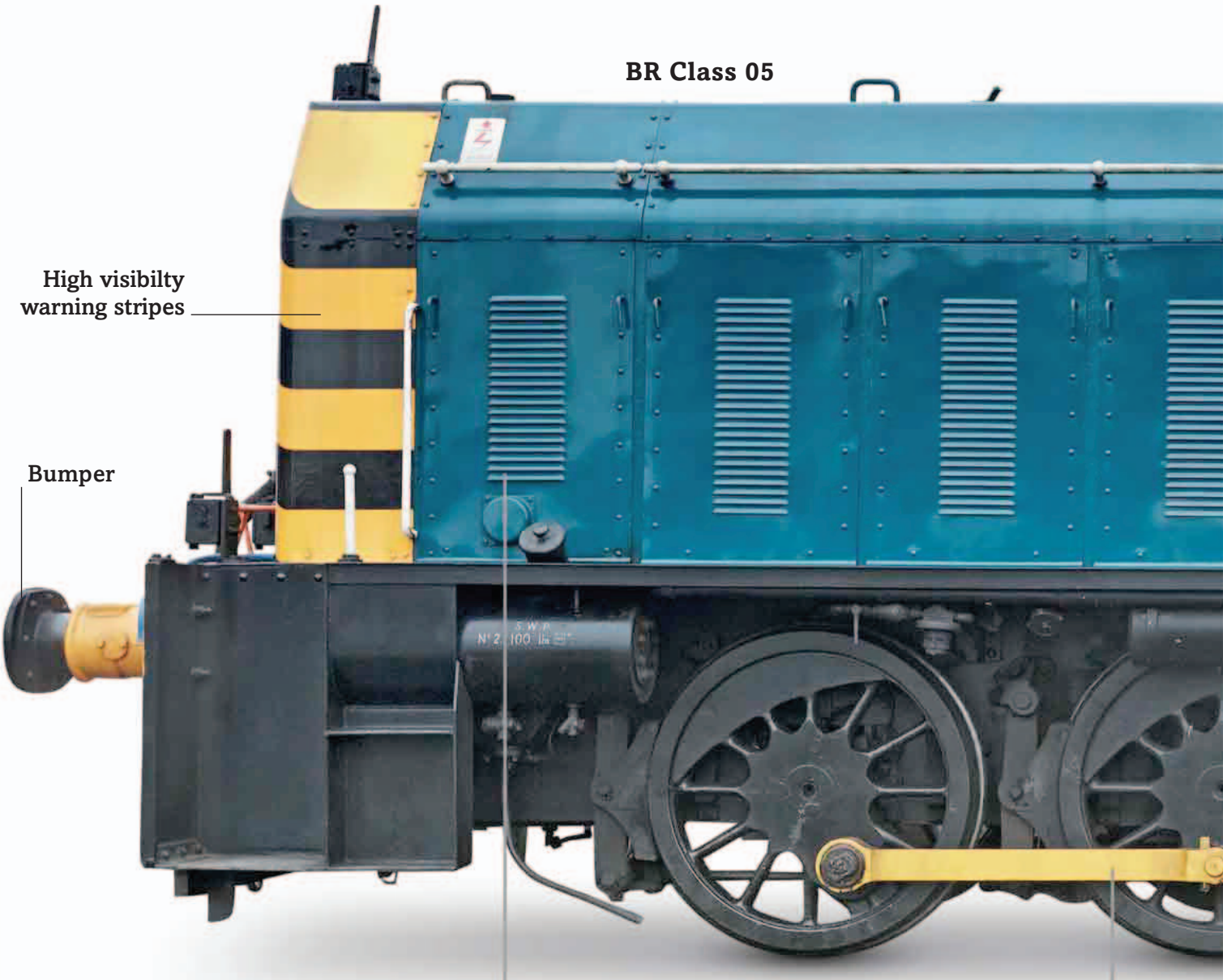
altitude. In contrast, the **Met Class A** ran on the world's first underground train line, the Metropolitan Railway in central London. Steam trains were built well into the 20th century. More than 3,700 **Prussian Class P8** engines were built and used in Romania, Poland, France, and elsewhere. Innovations included the **PP&L *D* Fireless**, which stored steam in its boiler so it could work in places where flammable fuel was a hazard. Steam engines were also streamlined for extra speed. The **Class A4 *Mallard*** was the fastest, with a top speed of 125 mph (202 km/h).

FLYING SCOTSMAN The No. 4472 *Flying Scotsman* powers along the tracks of the Carlisle to Settle line in the north-west of England, a service known as the "Cumbrian Mountain Express." The 71-ft-2-in- (21.7-m-) long locomotive weighed more than 109 tons, but generated enormous pulling power. In 1934, it became the first steam locomotive officially recorded to exceed 100 mph (160 km/h).

The *Flying Scotsman* was designed by the British engineer Sir Nigel Gresley, who had joined the railroad as a 17-year-old apprentice. The locomotive was built in 1923, and soon after was painted its famous apple-green color. During World War II, however, it was painted black. After 40 years of faithful service, the *Flying Scotsman* was retired by British Rail in 1963, but the engine's travels weren't over. It was saved from being scrapped by enthusiast Alvin Pegler and, after restoration, underwent a five-year tour of the USA, before being taken to Australia, where she set a new world record for the longest nonstop locomotive run, traveling 422 miles (679 km) on the Alice Springs to Melbourne route.

Diesel train

Diesel trains contain one or more large internal combustion engines that generate hauling power. This power is transferred to the wheels by different transmission systems. Locomotives using the diesel-mechanical system, such as this **BR Class 05**, transfer the power directly to the wheels by means of shafts and cranks. In a diesel-electric system, the power is converted into electricity in a generator, which drives the motors that turn the locomotive's wheels.



Ventilation grille › The grilles let air into the main body of the locomotive to help cool the large diesel engine.

Coupling rod › This transmits power from the engine to all three driving wheels on each side of the locomotive.

Engine › A large Gardiner eight-cylinder diesel engine gives this locomotive a lot of pulling power with the help of a four-speed gearbox. However, it has a low speed—18 mph (29 km/h).

Cab › The 11-ft-6-in- (3.5-m-) high cab gives a good view down the long hood, while twin rear windows allow the driver to see what is going on behind. Inside, a series of dials gives the driver details of the engine's speed, temperature, and status.

Dawn of diesel

High, sloping driver's windshield

Bugatti railcar France 1932

Eight-wheel bogie
(set of wheels that pivot)

122 mph (196 km/h)

GHE T1 Germany 1933

Body design
tapers at rear

25 mph (40 km/h)

The first GWR completed **59,652 miles** (96,000 km) in its first year.

Small, sliding windows

GWR streamlined railcar UK 1934

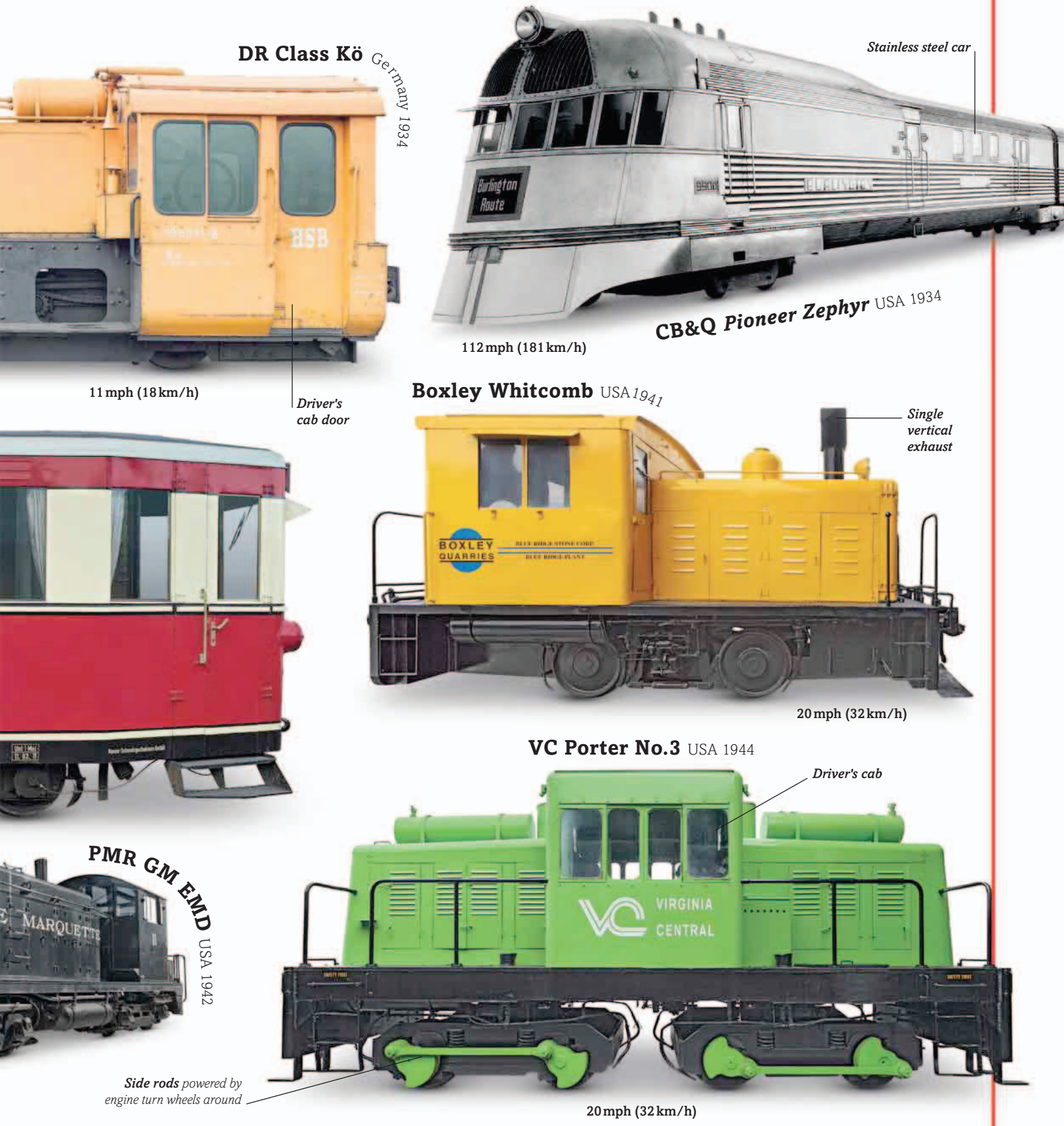
80 mph (129 km/h)

Headlight

45 mph (72 km/h)

As engine technology developed in the early 20th century, some engineers turned away from steam in favor of locomotives that ran on diesel fuel. Diesel-engined trains entered service in numbers from 1930s onward.

Diesel engines required less maintenance than steam locomotives and could be operated without extra crew to stoke the boiler. This made some, such as the **VC Porter No.3** and **DR Class Kö**, ideal as low-speed switchers. Many early diesel trains used their engines to drive the wheels



mechanically, but not the **PMR GM EMD**. A diesel-electric locomotive, its diesel engine powered a generator that supplied electricity to its four electric motors. Diesel engines were also used to power railcars—train passenger cars with motors fitted below. The **GHE T1** railcar could carry 34 passengers and ran on just four wheels. The **GWR streamlined railcar** had a top speed of 80mph (129km/h), while the **Bugatti railcar** was even faster. This sleek machine broke the record for high-speed trains in 1934 with a top speed of 122mph (196km/h).

Mainstream diesel

106 mph (171 km/h)

Powerful headlight to illuminate track ahead

Logo of the Norfolk and Western Railway

Baldwin Class DS-4-4-660 USA 1946

60 mph (96 km/h)

75 mph (125 km/h)

Stainless steel body is 85 ft (25.9 m) long

Budd RDC railcar USA 1949

85 mph (137 km/h)

Two **jet aircraft** engines were fitted to the roof of a Budd to set a speed record in 1966.

B&O F7 Class USA 1949

Ladder to driver's cab

50–120 mph (80–193 km/h)

Diesel locomotives became common after World War II. Although they were often more expensive to build, many were much cheaper and easier to operate than steam locomotives, and they spent less time in repair shops as well.

Baldwin Class DS-4-4-660 switchers were used to move cars and wagons in railroad yards. With their 660-horsepower diesel engines, some 139 were built. The rugged and reliable **N&W EMD GP9 Class** served all over the USA and Canada as a switcher, with more than

Spacious cab *provided at either end of the locomotive*

English Electric DP1 *Deltic* UK 1955

Driver's cab *mounted on the roof*

DB VT11.5 Germany 1957

100 mph (160 km/h)

N&W EMD GP9 Class USA 1955

Radiator cooling fans

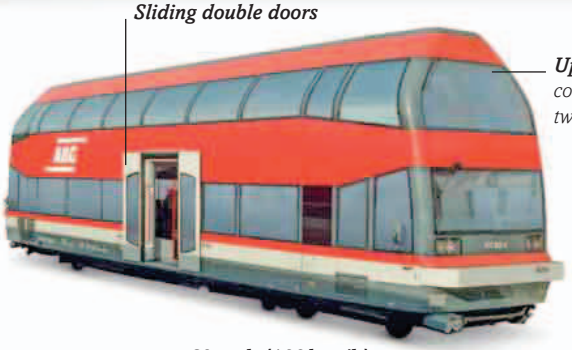
UP GM EMD Class SD60 USA 1984

Rounded fuel tanks

65 mph (105 km/h)

Sliding double doors

Upper deck *connected to lower by two spiral staircases*



60 mph (100 km/h)

DWA Class 670 railcar
Germany 1996

BR GM EMD Class 66 UK/USA 1998

75 mph (121 km/h)

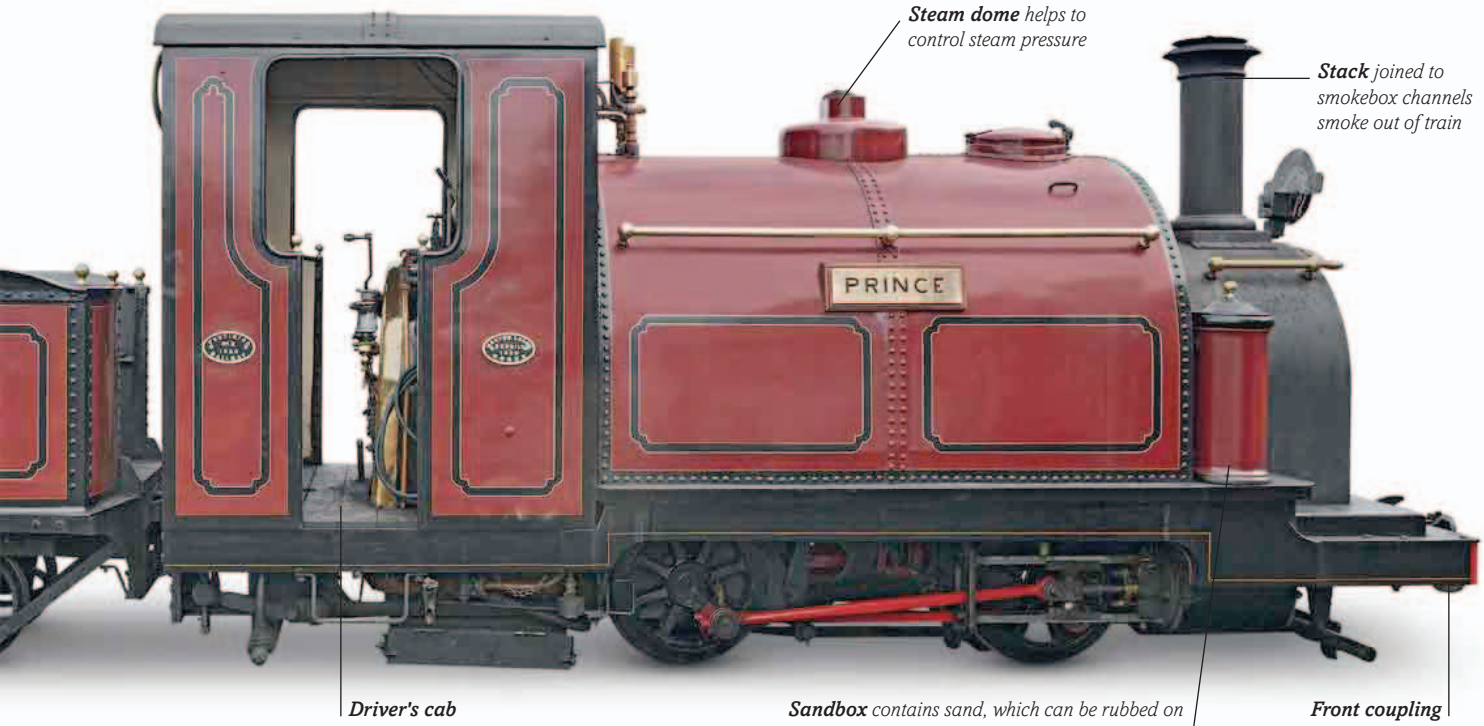
4,000 produced. The **DB VT11.5** hauled first-class passengers at speeds of up to 100 mph (160 km/h) on the famed Trans-Europ Express services, which linked 130 cities throughout Europe. Diesel-powered railcars, such as the **Budd RDC**, proved very versatile. On small lines, each railcar could operate by itself to carry a limited number of passengers, or they could be linked together for greater capacity. Another option was a double-decker, such as the **DWA Class 670 railcar**, which could hold up to 110 people on two decks.

Rail workhorses

Its long nose gave the Ce6/8 the nickname **Swiss Crocodile**.

While passenger trains grab all the attention, thousands of other trains are busy at work every day. These rail workhorses haul vast amounts of freight, and move other trains and cars around railroad yards.

Freight trains often use diesel engines, such as the **DR V100**, more than 1,100 of which have served across the world. The electric **SBB Class Ce6/8**, similar in design to the DR V100, has a central cab with a protruding nose at each end. The engine was hinged so that it could turn on



B&A GE 70-ton switcher USA 1946

BR Class 08 *Phantom* UK 1953

DR V15 Germany 1959

tight tracks in the Swiss mountains. Not all freight is carried cross-country. Many trains move goods and equipment on lines serving docks, mines, and factories, such as the **FR *Prince***, which hauled slate from Welsh mines. Many small locomotives are also used to move around cars, wagons, and larger locomotives, to assemble and disassemble train services. These switchers, such as the **DR V15** and the **BR Class 08**, had to be robust and reliable. More than 100 Class 08s are still in service more than 50 years later.

Going electric

A GG1 pulled the **funeral train** of President Franklin D. Roosevelt.

The 1880s saw electric streetcars and trolleys rattling around cities, and it was not long before electric trains appeared. They offered advantages over smoke-belching steam trains, but they needed electrified railroad lines on which to run.

Experimental electric trains had been built since the 1830s, but the first main line electric service was in Baltimore in the 1890s. The **B&O Bo Switcher** operated in Baltimore's docklands at a top speed of 9 mph (16 km/h). Electric trains get their power supply either from overhead cables or

SNCF Class BB9000 France 1954

Cowcatcher *pushes obstructions from the track*

Single pantograph *connects with overhead power lines of 11,000 volts*

Penn Central/Budd Metroliner USA 1969

DR Class 243 Germany 1982

The BR Class 92 was built to run in the **Channel Tunnel** linking England and France.

Locomotive weighs 141 tons

BR Class 92 UK 1993

via a third rail running along the track. The **NER** used both systems. After World War I, many countries began the electrification of their lines. The **GIPR Class WCP 1s** were the first electric engines to run in India. The 79-ft-3½-in- (24.2-m-) long **PRR Class GG1** was designed to travel around tight bends on American tracks. Electric railcars, such as the **Budd Metroliner**, also ran on American railroads. Electric trains proved to be reliable workhorses; more than 600 **DR Class 243s** were built for East German railroads to haul freight and passengers.

High-speed electric trains

Birmingham Airport Maglev UK 1984

26 mph (42 km/h)

***Train** is held ½in (15 mm) above the track by magnets*

DB ICE 3 Germany 2000

***Engineer's cab** separated from passenger seats by a glass panel*

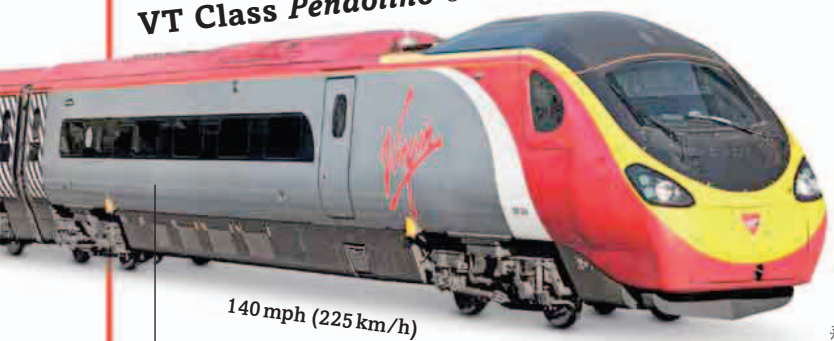
199 mph (320 km/h)

Shanghai Transrapid Maglev China 2004

249 mph (400 km/h)

***Magnets** raise the train around ⅜in (10 mm) above the guideway*

VT Class *Pendolino* UK 2002



140 mph (225 km/h)

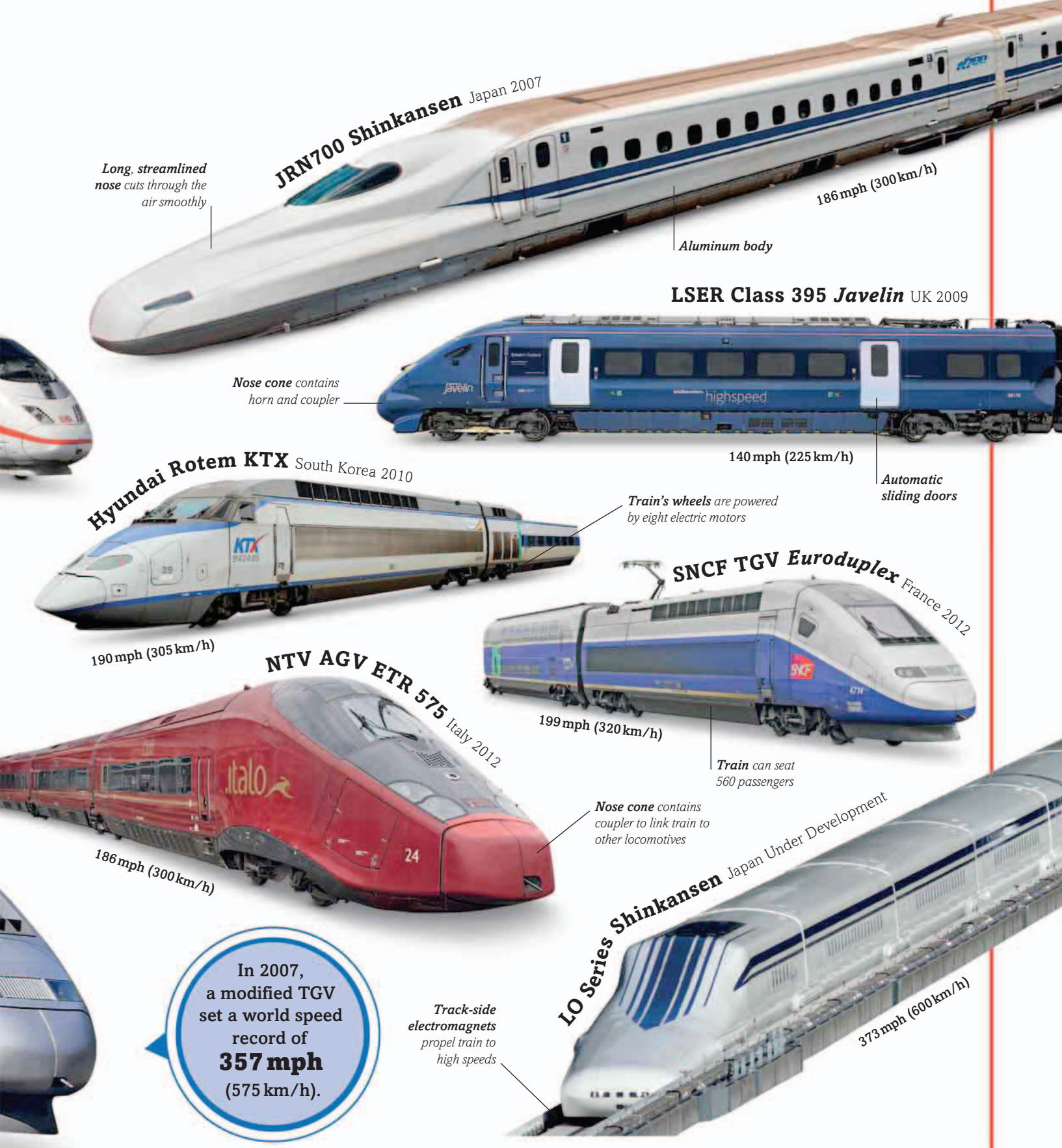
***Cabin** tilts up to 8 degrees when traveling on bends*

199 mph (320 km/h)

SNCF TGV POS France 2006

The need for speed has never been greater as high-speed trains take on aircraft and road traffic to get passengers from one point to another in the quickest possible time. Meet some of the most rapid railroad vehicles of all time.

The superfast **JRN700 Shinkansen** train can accelerate from 0 to 168 mph (270 km/h) in three minutes and can tilt slightly to keep its speed when moving around bends. While most high-speed electric trains, such as the **Hyundai Rotem KTX**, have powerful wheel-turning



In 2007, a modified TGV set a world speed record of **357 mph** (575 km/h).

electric motors housed in a power unit at the front of the train, the **DB ICE 3** has its motors spread out over the entire length of the train to distribute the weight. The **SNCF TGV *Euroduplex*** is a rare example of a high-speed double-decker train. Some trains use powerful electromagnets to raise them above their track and move them along. This is called magnetic levitation (maglev). The first public passenger maglev train was the **Birmingham Airport Maglev** in the UK, while the fastest is the **Shanghai Transrapid Maglev**, in China.

BULLET TRAIN Sleek, streamlined, and super-fast, a Japanese Shinkansen high-speed "bullet train" speeds across Honshu Island past snow capped Mount Fuji. In 2014, Japan celebrated 50 years since Shinkansen trains ran for the very first time, just before the 1964 Tokyo Olympic Games. Today, Japan's high-speed rail network has carried more than 11 thousand million passengers.

The first Shinkansen trains ran at speeds of up to 130 mph (210 km/h). The latest classes of trains take their power from 25,000 volt overhead electricity lines and can reach a top speed of 200 mph (320 km/h). The trains run on their own lines, separate from slower rail traffic—a total of 1,483 miles (2,387 km) of high-speed track crosses Japan. As many as 13 bullet trains per hour fly between Japan's two biggest urban areas, Tokyo and Osaka, providing an unrivalled high-speed service. Before the bullet trains were introduced, journey time between the two cities was around 6 hours, 40 minutes. The fastest services today complete the route in just 2 hours, 35 minutes.

Urban railroads

Single, large wiper *cleans entire windshield*

Mud Island Monorail USA/Switzerland 1982

Suspended car *can hold up to 180 passengers*

Gatwick Adtranz C-100 UK/Canada 1987

Train *runs on wheels fitted with rubber tires*

SMRT North-South Line C151 Singapore 1987

Train *travels at speeds up to 50 mph (80 km/h)*

Articulated joints *between short cars*

Berlin U-Bahn
Germany 1992

Trains on the Berlin U-Bahn carry over **508 million** passengers every year.

Rail services in towns and cities ferry millions of people every day. Some travel for work or for school, others for fun and leisure. There are urban railroads that link airports with towns, while others help reduce congestion on city roads.

Rapid transit systems, such as the **Matra Taipei Metro**, offer quick and reliable transportation between city stations separated by short distances. To avoid cluttering up the streets, many train lines run underground. The **Berlin U-Bahn** has 80 percent of its 90 miles

Siemens Avanto Germany 1995

Matra Taipei Metro Taiwan/France 1996

Rail supplies *750-volt electricity to power train's motors*

Hollow box girder *contains cable along which train's wheels run*

Düsseldorf H-Bahn Skytrain Germany 2002

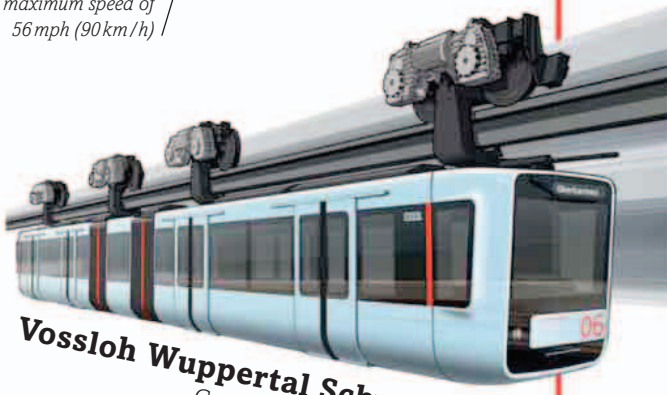
Bombardier MOVIA Canada/Singapore 2000s

Large windshield *on engineer's cab*

Moscow Monorail Russia 2004

Driverless train *has a maximum speed of 56 mph (90 km/h)*

Automatic coupler, *to link with other trains*



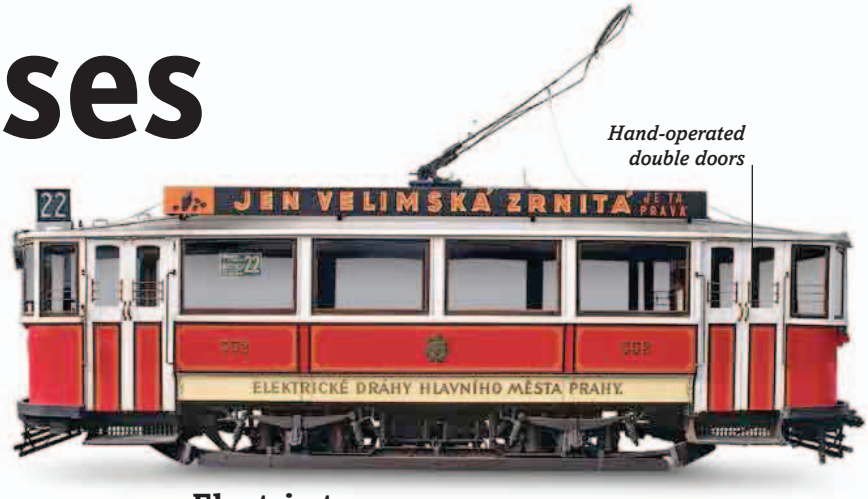
Vossloh Wuppertal Schwebebahn Germany 2015

(146 km) of lines running below the surface of the city. Monorails are trains that run on a single rail. Many, such as the **Moscow Monorail**, have their trains running on top of the rail, while some, such as the **Mud Island Monorail**, are suspended below the rails. While many urban trains are controlled by a human driver, some systems run automatically. The **Gatwick Adtranz**, the **Düsseldorf H-Bahn Skytrain**, and the popular **Bombardier MOVIA**, which runs in Singapore and China among other countries, are driverless vehicles.

Streetcars and trolleybuses

Great Orme Tramway UK 1902

Streetcar *pulled uphill by cable moved by electric motors*



Hand-operated double doors

Electric tram Czech Republic 1907

Pantograph *connects tram with overhead electricity supply*

W2 Class Melbourne tram Australia 1927

This W2 Class *has been converted into a restaurant on wheels*

Wheels *powered by four electric motors*

English Electric Balloon
UK 1934

Several **Balloon** streetcars run in Blackpool, England, **80 years** after they were built.

Hong Kong Tramways
China 1980s

Streetcars run on tracks, are powered by electricity supplied by overhead cables, and share space on streets with other vehicles. They are also known as trams. Trolleybuses are also electrically powered, but they run on tires instead of tracks.

Britain's first electric tramway was built in Blackpool in 1885. The double-decker **English Electric Balloon**, which could hold up to 94 passengers, ran along at speeds of up to 43 mph (70 km/h). The **Hong Kong Tramways** is an all-double-decker service—the only one in the

Some **CAF** trams run an average distance of **59,030 miles** (95,000 km) per year.

Flexity Swift M5000 Canada/Germany 2009

Aluminum body panels

Seats up to 66 passengers

CAF Urbos 3 Spain 2009

Five articulated segments allow tram to travel around bends

Low floor sits 13¾in (35cm) above the track

Trolley pole channels electricity from overhead wire to trolleybus

Solaris Trollino 15 Poland 2001

San Francisco Trolleybus USA 2003

Belkommunmash 42003A Belarus 2007

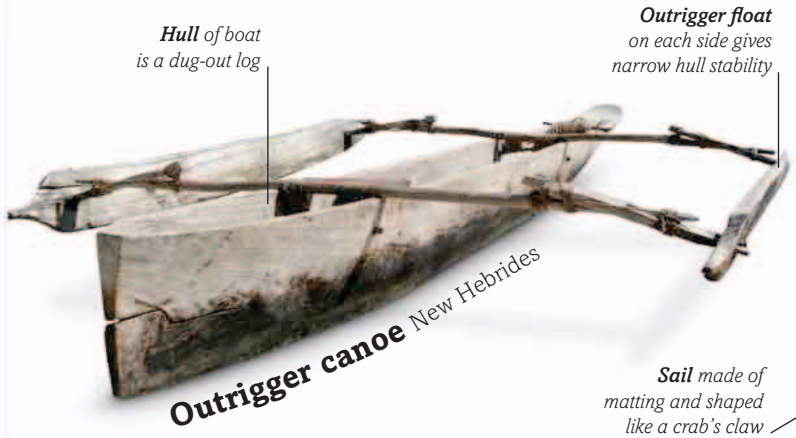
world—and uses narrow trams, only 6 ft 5 in (1.98 m) wide. Modern streetcars such as the **Flexity Swift** are found in Manchester, Istanbul, and Cologne, while the **CAF Urbos 3** runs on tramways all over the world, from Australia and Brazil to Taiwan and Spain. Trolleybuses, such as the **San Francisco Trolleybus** and the **Solaris Trollino 15**, run on regular roads and need only a series of roadside poles from which their overhead power line is suspended. The Trollino is quieter and generates much less pollution than buses powered by gasoline or diesel engines.

HOLD ON TIGHT! Followers of the Hindu religion crowd a train on its way to the northern Indian town of Govardhan, to take part in the Guru Purnima festival. Indian locomotives and train cars are not normally as crowded as this, but the country does run one of the largest and busiest railroad systems in the world, with enough track—some 71,500 miles (115,000 km) in total—to circle the Earth almost three times.

This WDM-3A class locomotive is just one of 5,345 diesel engines that runs along the tracks of Indian Railways. The company also operates 4,568 electric locomotives and 43 steam engines. These haul more than 62,000 passenger cars and 239,000 freight wagons, stopping at more than 7,200 stations throughout India. Some services also travel over the border, into the neighboring countries of Pakistan, Nepal, and Bangladesh. In India the cost of train fares is low, and the number of car owners relatively small, so rail travel is incredibly popular. In 2014, more than 8.5 billion passengers took the train, giving Indian Railways' 1.3 million employees plenty of work to do.

WATER

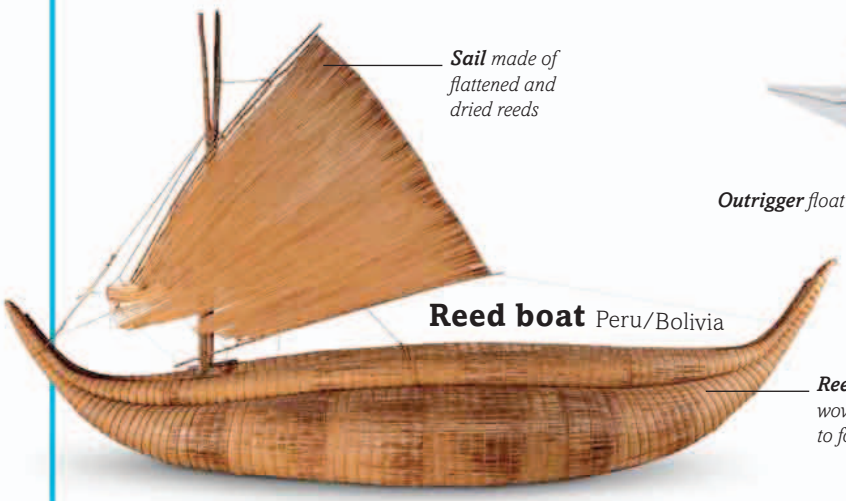
Taking to the water



Outrigger canoe New Hebrides

Some Pacific sailors used the sail to **collect rain** as drinking water.

Crab claw log boat Solomon Islands



Reed boat Peru/Bolivia

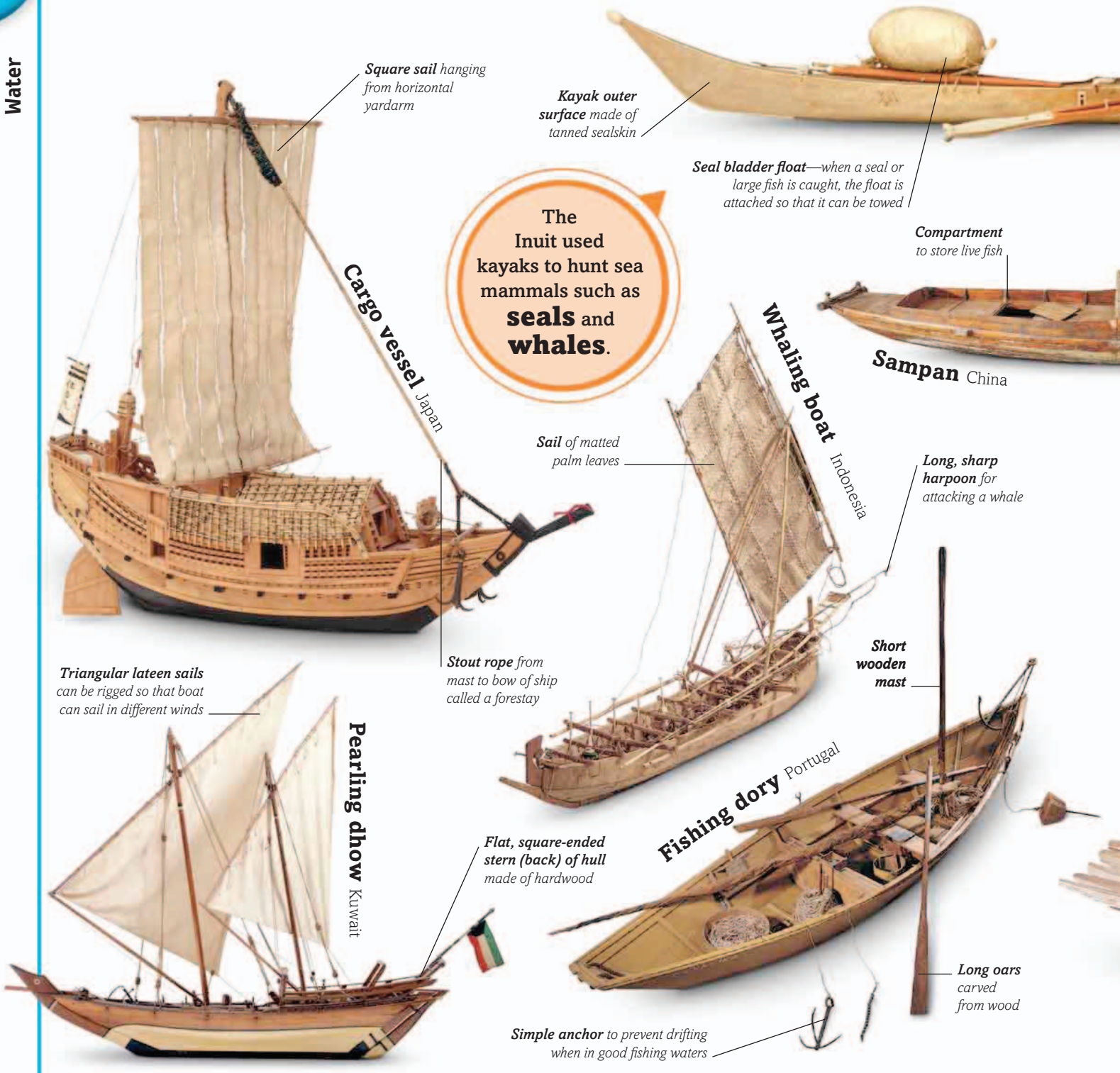
Seagoing boat Ancient Egypt

No one knows the name of the first sailor, or the craft that he or she used. They may have sat astride a log, or on bundles of reeds, lashed together. What we do know is that people have travelled or fished in boats for more than 10,000 years.

Some of the earliest boats were large tree trunks, hollowed out to form simple **dugout canoes**. Ancient people throughout the Pacific learned how to build **outrigger canoes**, with a second, smaller hull floating on the water to provide stability, while the Native American people built

bark canoes out of a wooden frame covered in tree bark. Reeds, which grow in abundance at the edges of many rivers and lakes, were dried, bound, and woven to form **reed boats**. Reeds could also be woven to form circular boats for fishing. Known as **Thung-chai** in Vietnam, and coracles in UK, a similar form of boat called a **Quffa** existed in Iraq for at least 5,000 years. The ancient Egyptians built reed boats to sail the Nile River; around 5,500 years ago, they began to build larger, wooden **seagoing boats** to venture beyond the Nile into the Mediterranean Sea.

World of watercraft



An amazing variety of vessels have been built to travel on water. Across the world, people have used ingenuity, and the local materials available, to build boats, rafts, canoes, and other watercraft, for fishing, transportation, war, and pleasure.

Among the simplest boats are **fishing rafts**, often just a bundle of tree branches lashed together to form a platform. The raft-like **Jangada**, however, is able to sail over reefs on the Brazilian coast to fish for hake and mackerel, often spending 2 to 3 days at sea. Throughout

Battle canoes could be more than 100 ft (30 m) long and hold up to 200 warriors.

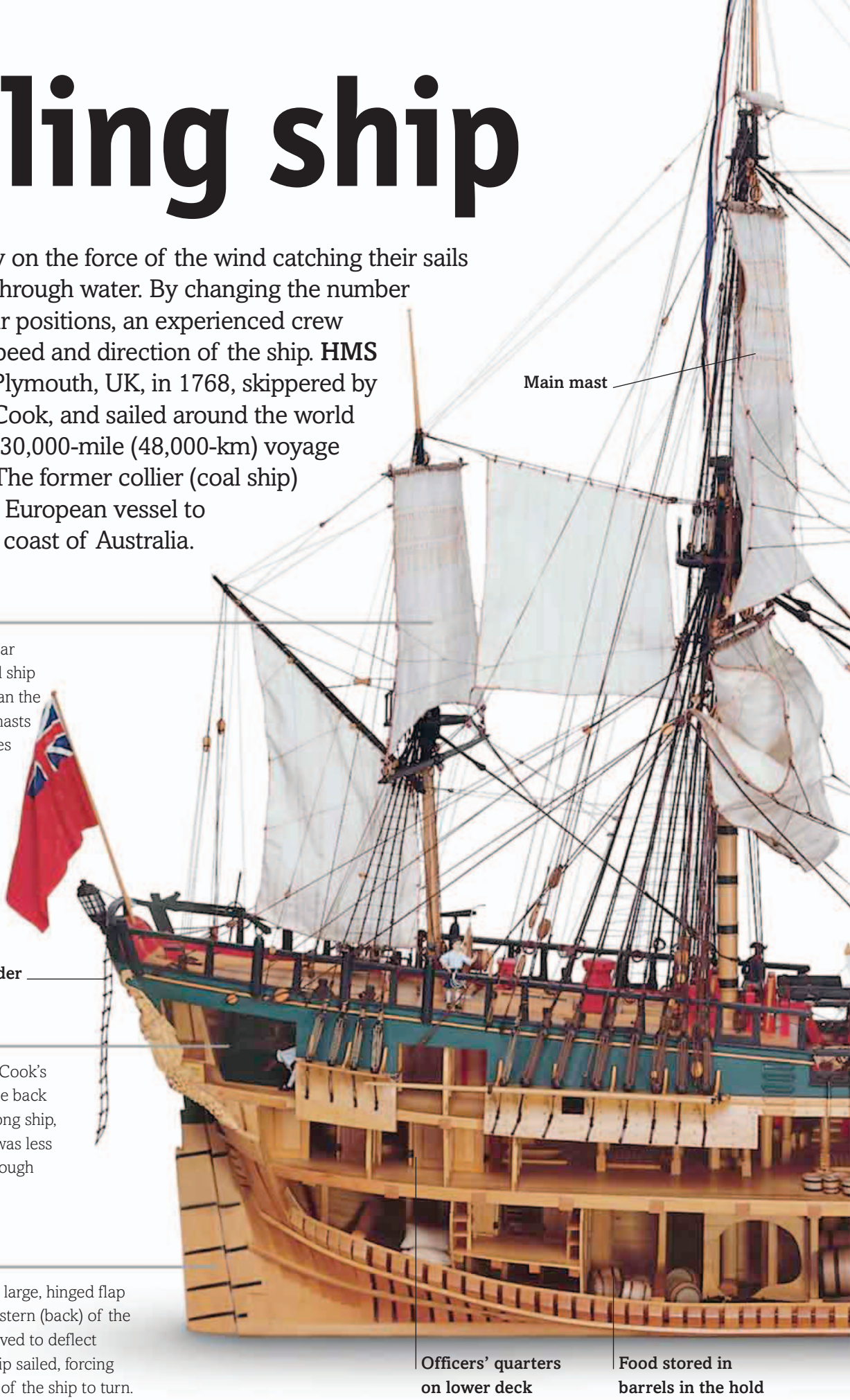
Southeast Asia, another flat-bottomed boat, the **sampan**, is used by people to fish, travel, and even live in. In the Arctic, single- and two-person **Inuit kayaks** were used to hunt for mammals and fish, while in Indonesia, brave hunters chased after sperm whales, often two or three times longer than their flimsy **whaling boats**. On the Pacific island of Fiji, people built larger **battle canoes**, featuring a platform laid over a double hull. And in Italy, slender **gondolas** travel the canals that crisscross the city of Venice, acting as water taxis.

OVER THE TOP A kayaker takes a terrifying plunge, hurtling over the highest of the five cascading waterfalls on the Agua Azul River in the Mexican state of Chiapas. He's one of six top professional kayakers who tackled the river and its waterfalls for the short adventure movie *Beyond The Drop*. For a safe landing, the kayaker must keep inside the flow of water, and land in the cushion of air and water at the foot of the waterfall.

It is likely that the first canoes and kayaks took to the water thousands of years ago, and that most were built of wood. But the appeal of paddling your own personal watercraft still holds today, even if modern canoes and kayaks are usually built from plastics, fibreglass, or, in the case of the most advanced, Kevlar and carbon fibre. Thousands of amateur kayakers enjoy paddling on rivers, lakes, or the sea, on weekends or on vacation. A handful of the best kayakers compete in competitions, either in speed races on flatwater, or on very technical whitewater slalom courses. Extreme kayaking is an adventure sport for the crazy few who enjoy paddling down racing rivers, including giant waterfalls!

Sailing ship

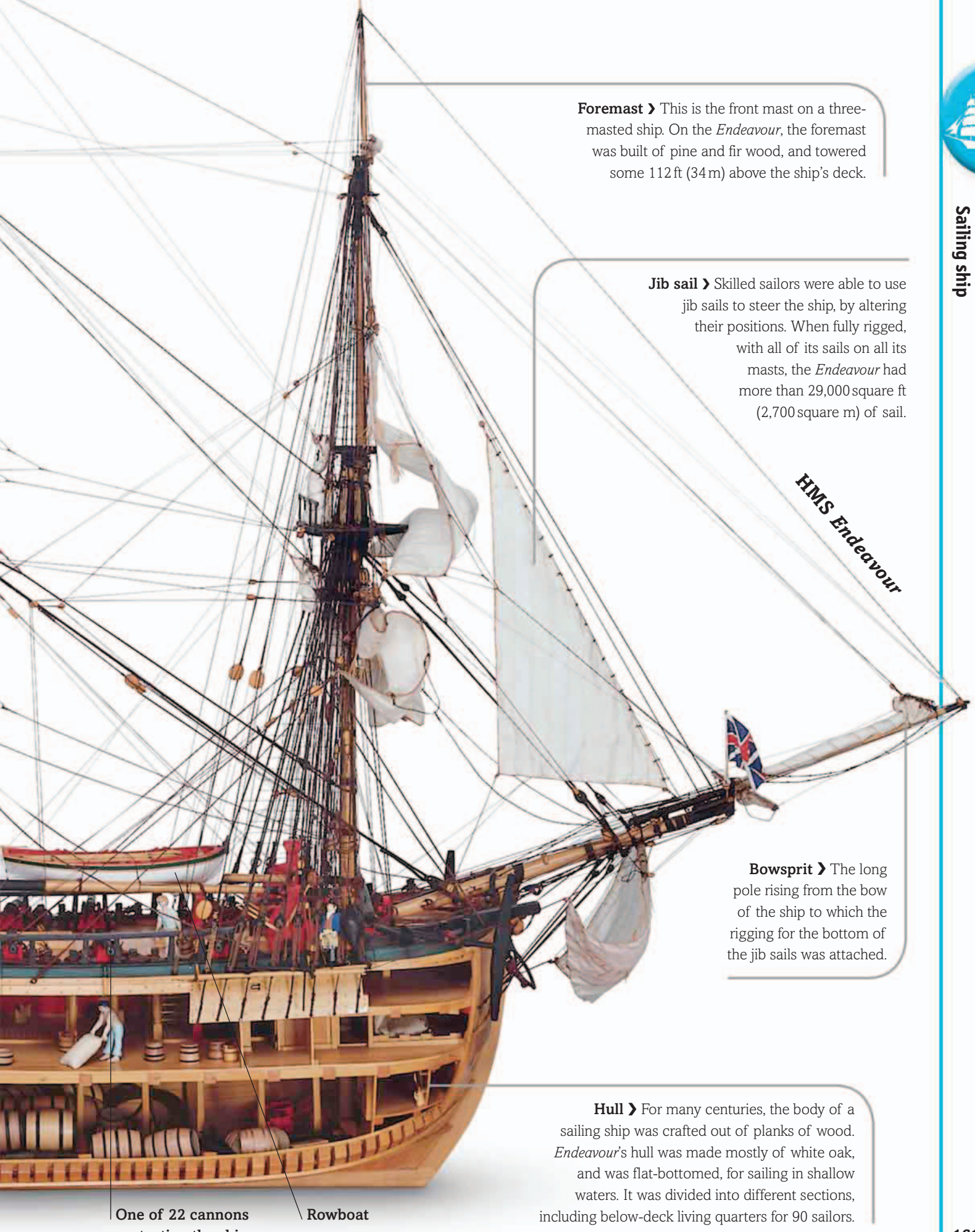
Sailing ships rely on the force of the wind catching their sails to propel them through water. By changing the number of sails, and their positions, an experienced crew can adjust the speed and direction of the ship. **HMS *Endeavour*** left Plymouth, UK, in 1768, skippered by Captain James Cook, and sailed around the world on a three-year, 30,000-mile (48,000-km) voyage of exploration. The former collier (coal ship) became the first European vessel to explore the east coast of Australia.



Mizzen mast › The rear mast on a three-masted ship tended to be shorter than the other two. Sails on all masts are hung from long poles called spars.

Captain's quarters › Cook's cabin was situated at the back of the 104-ft- (32-m-) long ship, where the rise and fall was less violent when sailing through stormy waters.

Rudder › This large, hinged flap or panel at the stern (back) of the ship can be moved to deflect water as the ship sailed, forcing the bow (front) of the ship to turn.



Foremast › This is the front mast on a three-masted ship. On the *Endeavour*, the foremast was built of pine and fir wood, and towered some 112 ft (34 m) above the ship's deck.

Jib sail › Skilled sailors were able to use jib sails to steer the ship, by altering their positions. When fully rigged, with all of its sails on all its masts, the *Endeavour* had more than 29,000 square ft (2,700 square m) of sail.

HMS *Endeavour*

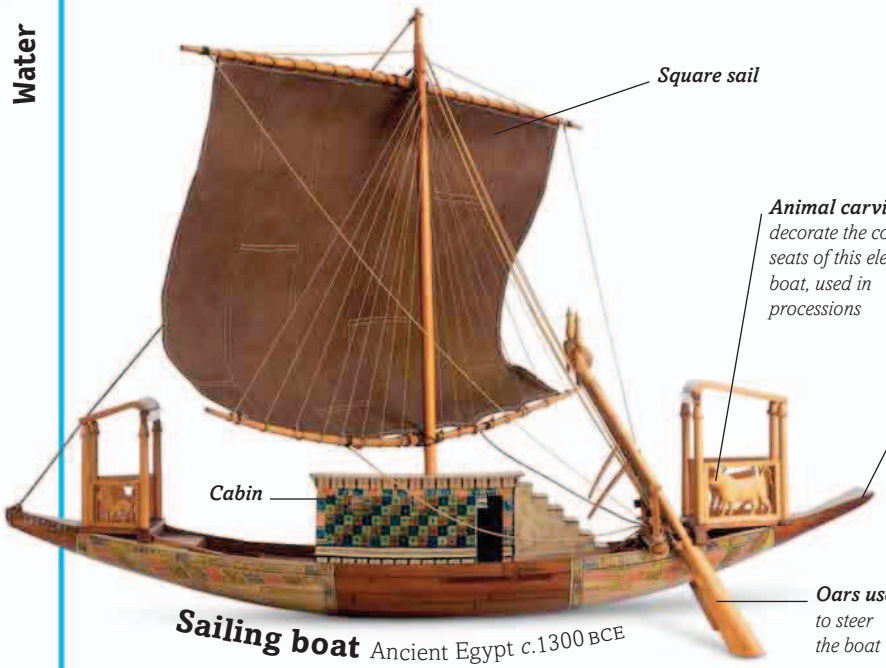
Bowsprit › The long pole rising from the bow of the ship to which the rigging for the bottom of the jib sails was attached.

Hull › For many centuries, the body of a sailing ship was crafted out of planks of wood. *Endeavour*'s hull was made mostly of white oak, and was flat-bottomed, for sailing in shallow waters. It was divided into different sections, including below-deck living quarters for 90 sailors.

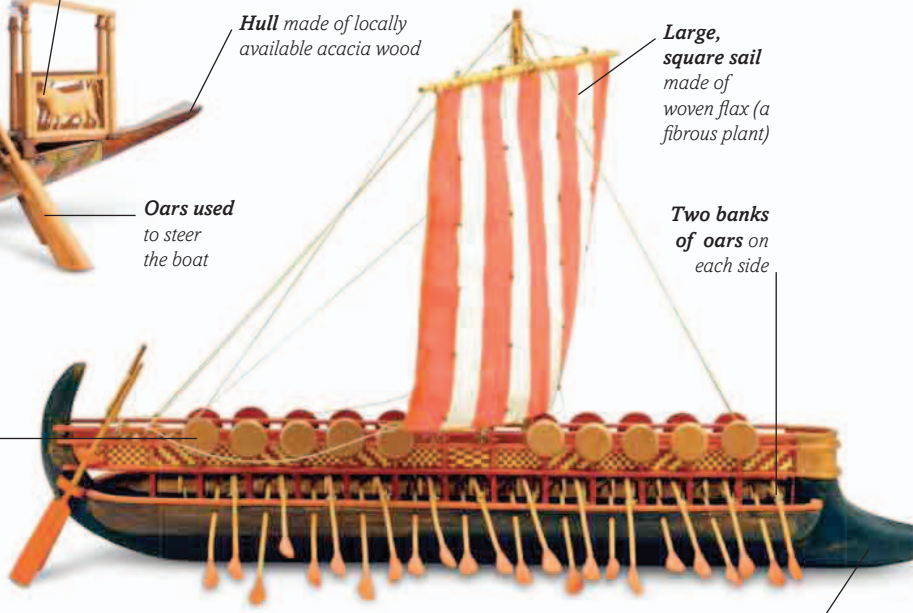
One of 22 cannons protecting the ship

Rowboat

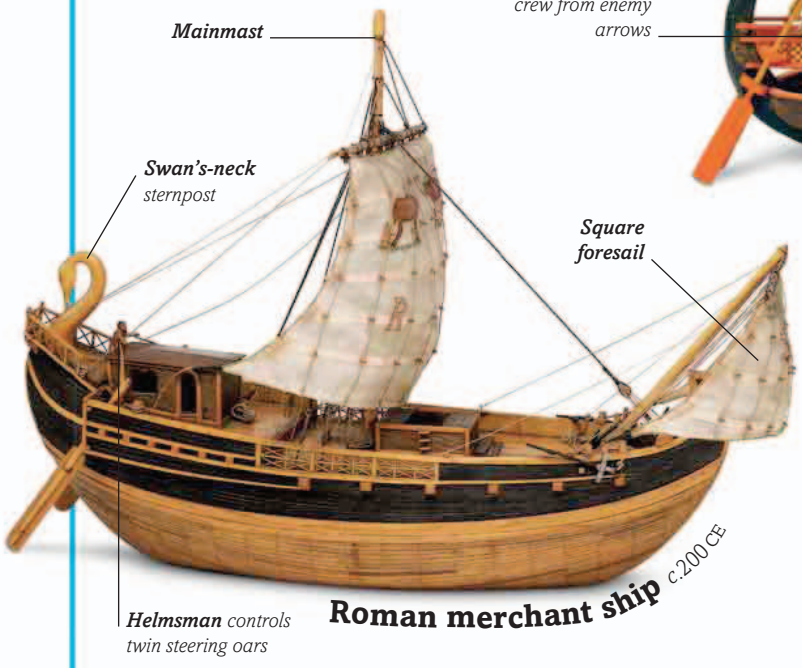
Sail power



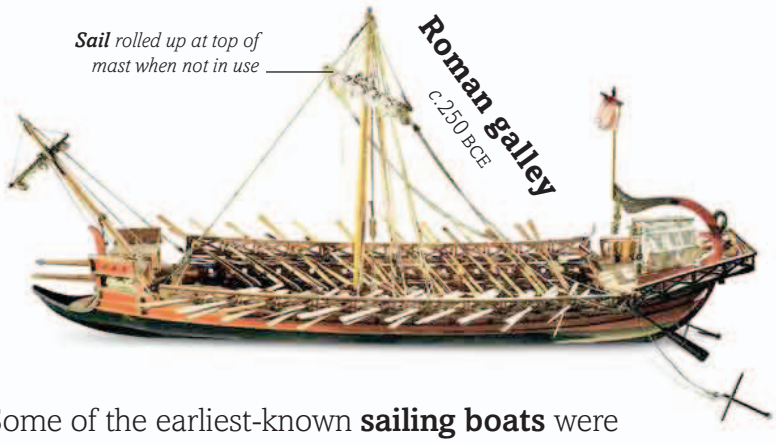
Sailing boat Ancient Egypt *c.*1300 BCE



Phoenician war galley *c.*700 BCE



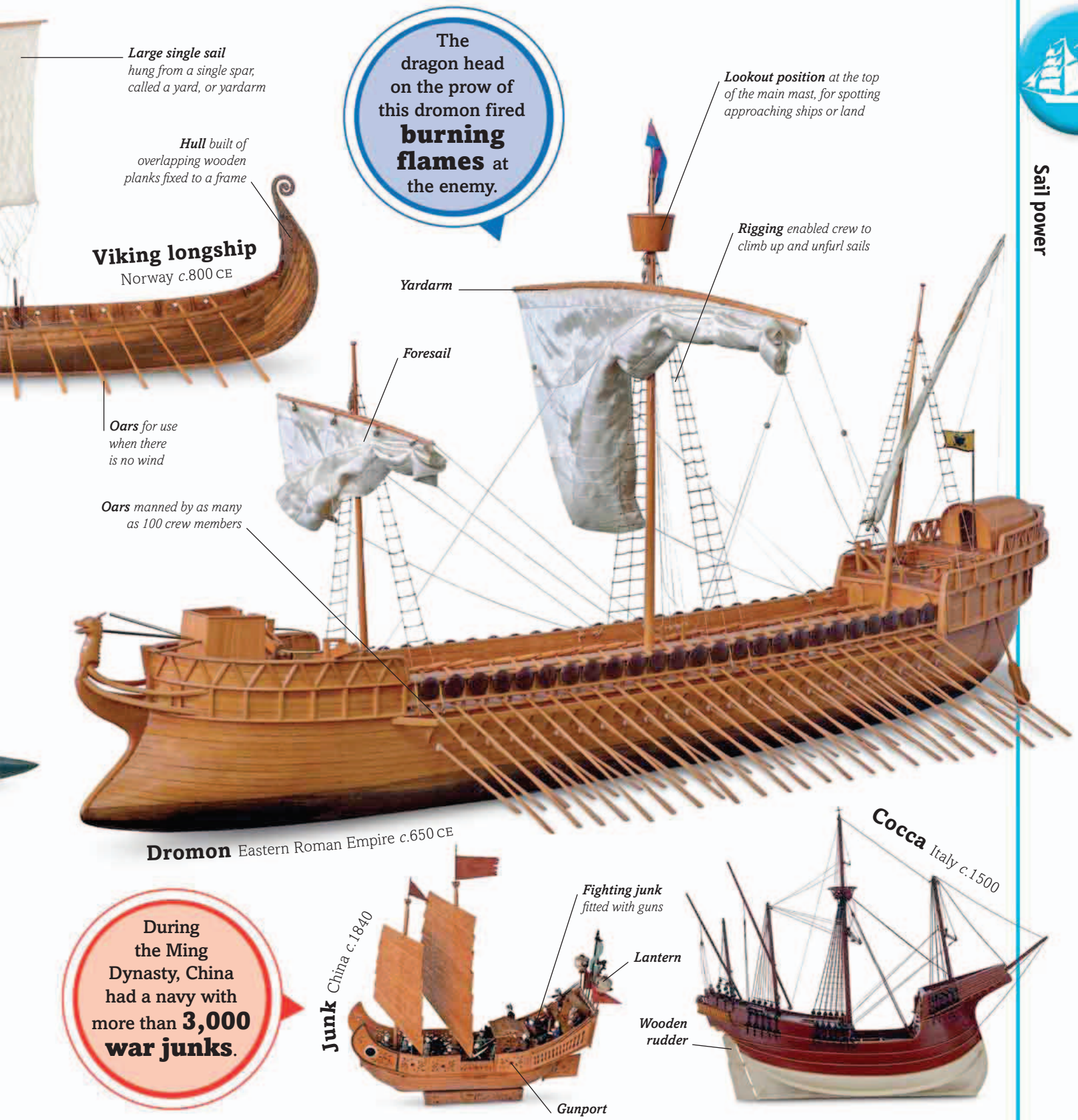
Roman merchant ship *c.*200 CE



Roman galley *c.*250 BCE

Thousands of years ago, people learned to harness the power of the wind to push their craft through the water. Sails made of cloth, reeds, or matting, and hung from a mast, caught the wind to move boats faster than people could row or paddle.

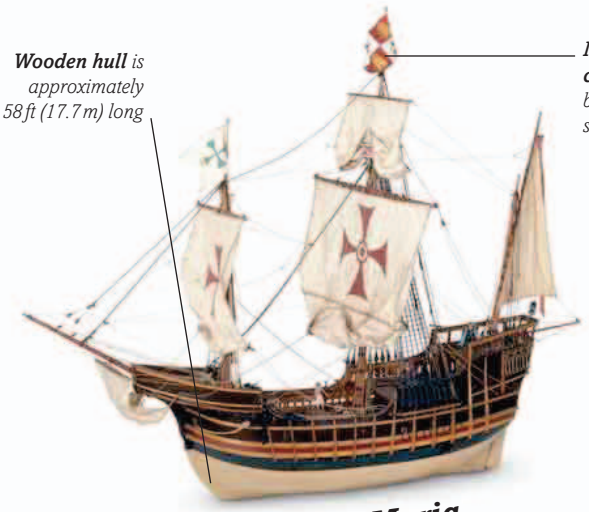
Some of the earliest-known **sailing boats** were found on the Nile River in Egypt, more than 5,000 years ago. They used a large, square sail made of cloth, which worked best when sailing downwind (with wind coming from behind the boat). Square sails were also invented independently in parts of



South America, and also in China, where they were often equipped to the **junks** that sailed the Pacific and Indian oceans. Many ancient sailing ships, such as **Phoenician war galleys**, **Roman galleys**, and **Viking longships**, were fitted with rows of oars, for when there was no wind.

Viking longships were designed with shallow hulls so they could sail right up to the shore to attack and raid settlements. The Vikings were skilled sailors who traveled all across Europe and, around 1000 CE, crossed the Atlantic reaching Newfoundland in Canada.

Trade and exploration



Wooden hull *is approximately 58 ft (17.7 m) long*

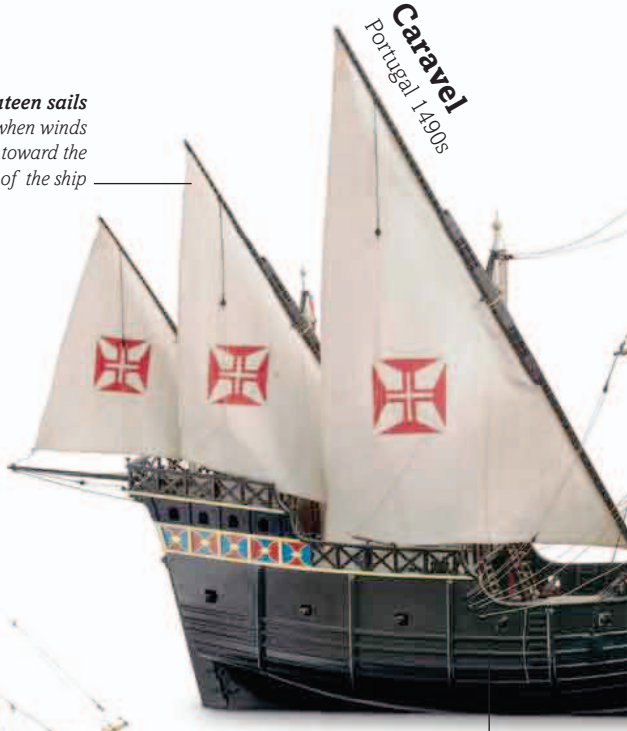
Main mast top castle *manned by crew member searching for land*

Santa Maria Spain 1460

When the *Santa Maria* was finally **broken up**, the wood was used to build a **fort**.

Hull *is approximately 90 ft (27.5 m) long*

Mayflower England 1600s



Lateen sails *used when winds blew toward the side of the ship*

Caravel Portugal 1490s

Short, deep wooden hull *could carry plenty of cargo below decks*

HMS Bounty England 1784

Hull *converted to transport breadfruit plants from Tahiti to the Caribbean*

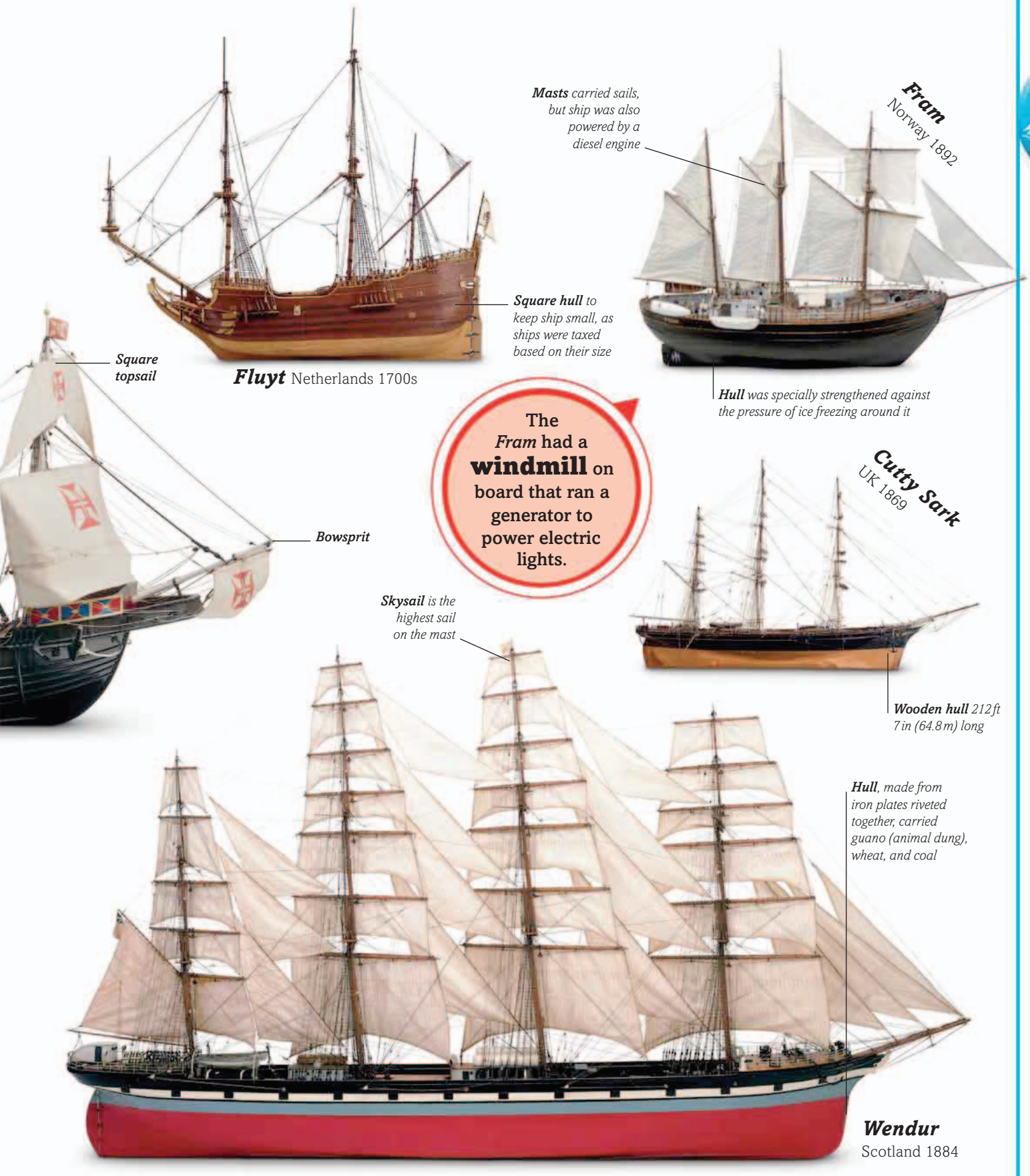
Mizzen mast *added to ship when it was converted from a warship to a survey vessel*

HMS Beagle England 1820

Ship *carried 74 people on a five-year survey voyage*

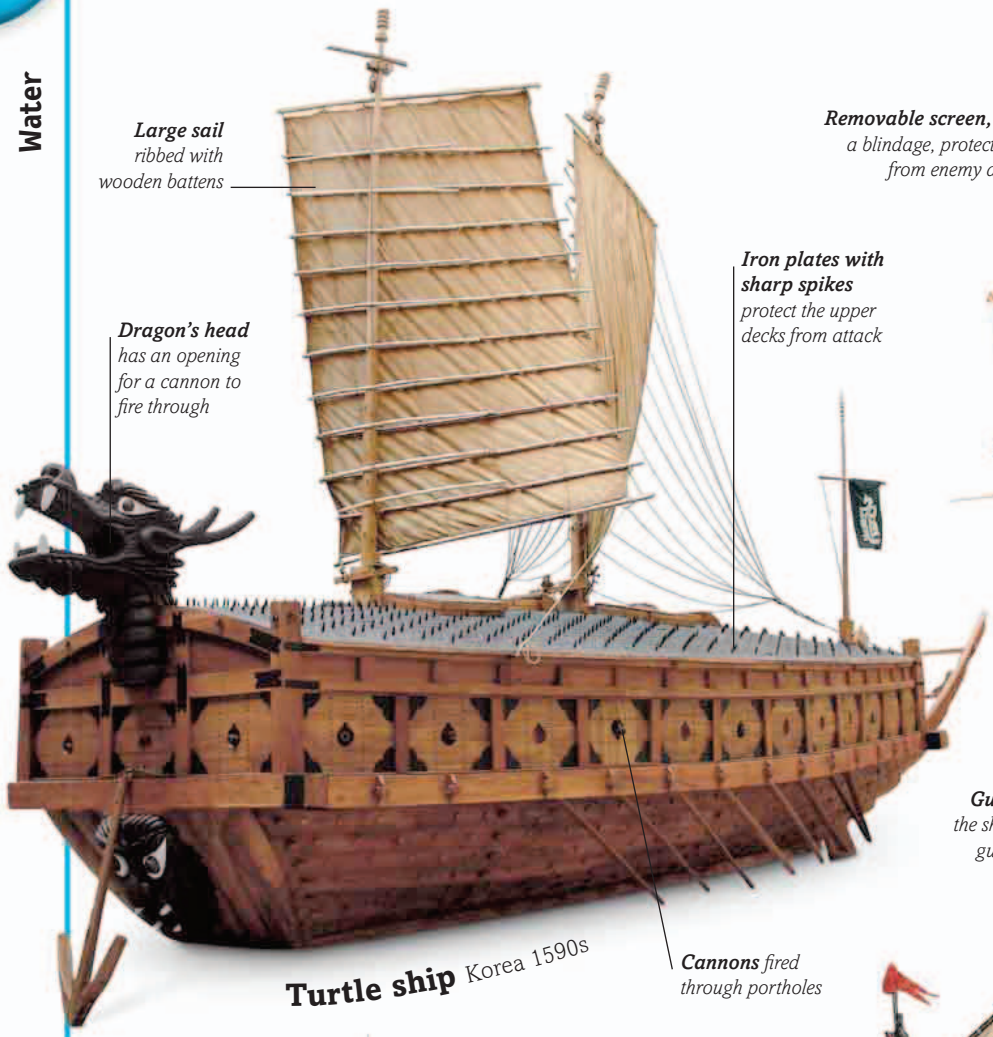
From the 15th century onward, European sailing ships traveled the world. Many were trading vessels, carrying cargoes as varied as slaves, food, and spices. Others explored new lands, on epic voyages of discovery.

Portugal was a major sea trading nation in the 15th century, and **caravels** sailed along the coasts of Europe and Africa. Two accompanied the ***Santa Maria*** on Christopher Columbus' famous 1492 voyage across the Atlantic. Many European ships would later head west for trade, or to conquer, or



establish colonies, such as the ***Mayflower***, which carried pilgrims to settle in North America. As European explorers found new lands, more merchant ships engaged in trade. The ***fluyt*** was a common Dutch design with a very narrow deck. Fast ships called clippers, such as the ***Cutty Sark***, sailed between Asia and Europe. One of the most epic trips of all was made by ***Fram***, which sailed more than 60,000 miles (100,000 km) around the Arctic, before carrying Norwegian explorer Roald Amundsen to Antarctica, where he became the first person to reach the South Pole.

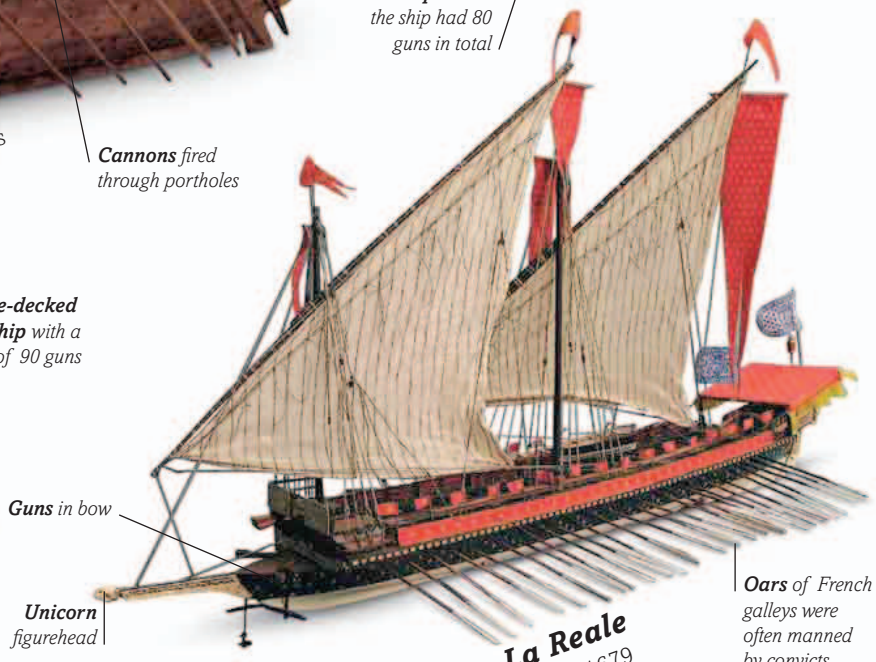
War at sea



Turtle ship Korea 1590s

Mary Rose England 1510

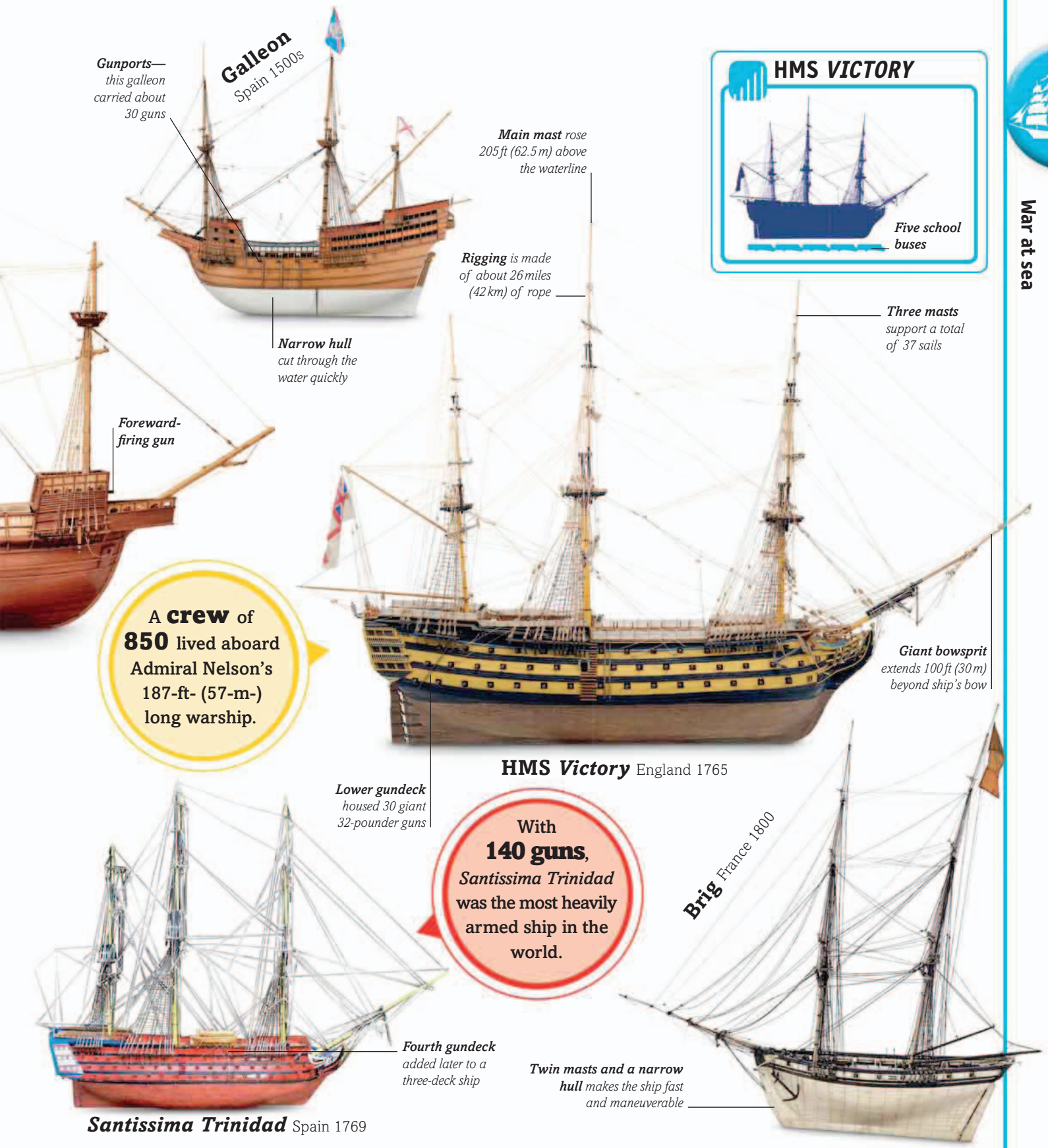
St. Michael England 1669



La Reale France 1679

For almost as long as there have been ships, the sea has been a battlefield for rival nations planning invasion, or for control of shipping routes and trade. From the 16th century, warships bristled with guns and battles at sea became even more deadly.

Before naval artillery, battles at sea were mostly close combat, with fire, rams, or arrows used in attack. The Korean **turtle ship** protected itself against archers, and from being boarded, with its hefty, spiked deck armor. Big guns allowed ships to fight more at a distance. The ***Mary Rose's*** iron



cannons fired through flaps called gunports, in the hull. To boost firepower, some ships were built with extra decks of guns. This led to three-decker warships, such as the ***St. Michael***, which fought in the Caribbean, and the ***Santissima Trinidad***, which later received a fourth deck of heavy guns.

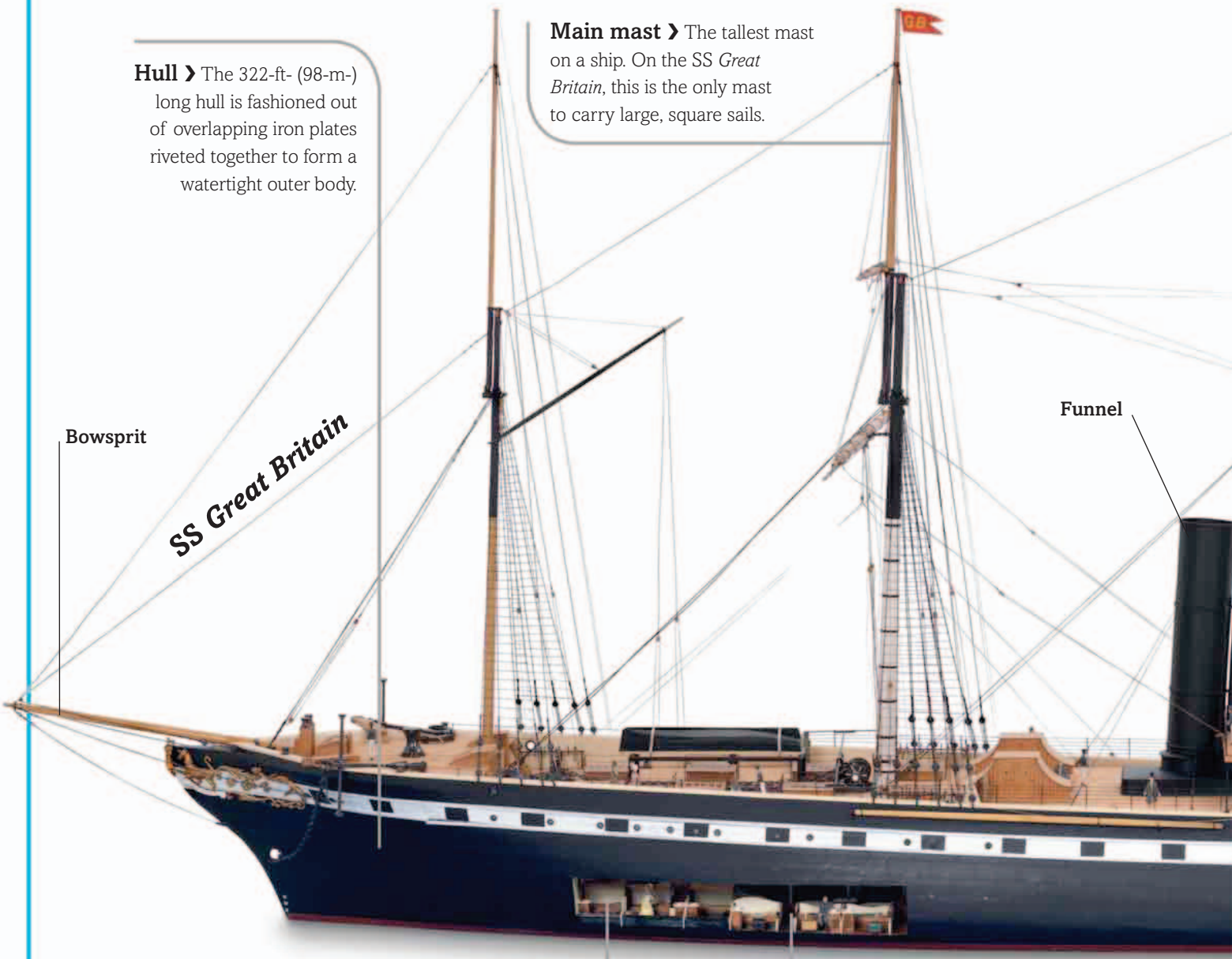
This made her menacing, but slow. Flagships, such as the French navy's ***La Reale***, were home to a fleet's commander. **HMS *Victory*** was the flagship under British admiral Lord Nelson at the battle of Trafalgar. With 104 guns, she was a formidable, as well as fast, fighting machine.

RIDING THE WIND The BMW Oracle Racing Team 90 (BOR90) trimaran (three-hulled boat) lifts up into the air during a training run. The 113-ft- (34.5-m-) long, 90-ft- (27.4-m-) wide giant is about the same size as two basketball courts and was built to win the America's Cup, sailing's most prestigious competition, which it did in 2010. The picture shows how racing sailors better not be afraid of heights!

Trimaran BOR90 (later renamed USA–17) needed more than nine months of careful construction in the state of Washington before it could be let loose on the water for testing, crew training, and modifications. Its body is made mostly of carbon fiber and weighs 18 tons. The main sail is not made of fabric, but is solid and made of carbon fiber and Kevlar, a material found in bulletproof armor. The result was a 190-ft- (58-m-) tall monster sail. At 7,770 lb (3,524 kg), it was so heavy that powerful hydraulic systems were needed to move it, rather than regular rigging, but it boosted the trimaran's speed to more than 30 mph (50 km/h) during parts of its triumphant America's Cup run.

Steamship

Steamships burned coal or oil to heat water and create steam to power an engine. This either drove a paddle wheel or turned a screw propeller, as found on the ***SS Great Britain***. When launched in 1843, SS *Great Britain* was the largest ship in the world, and the first iron-hulled steamship powered by a screw propeller. Two years later, it became the first propeller-powered steamship to cross the Atlantic Ocean, a journey that took 14 days.



Rigging › On the SS *Great Britain*, the rigging is made of iron cable rather than rope. This is to reduce drag.

Mast › Five of the ship's masts can be folded down on deck to reduce air resistance when the ship is solely under steam power.

Spar › Sails are hung from these long poles attached to masts.

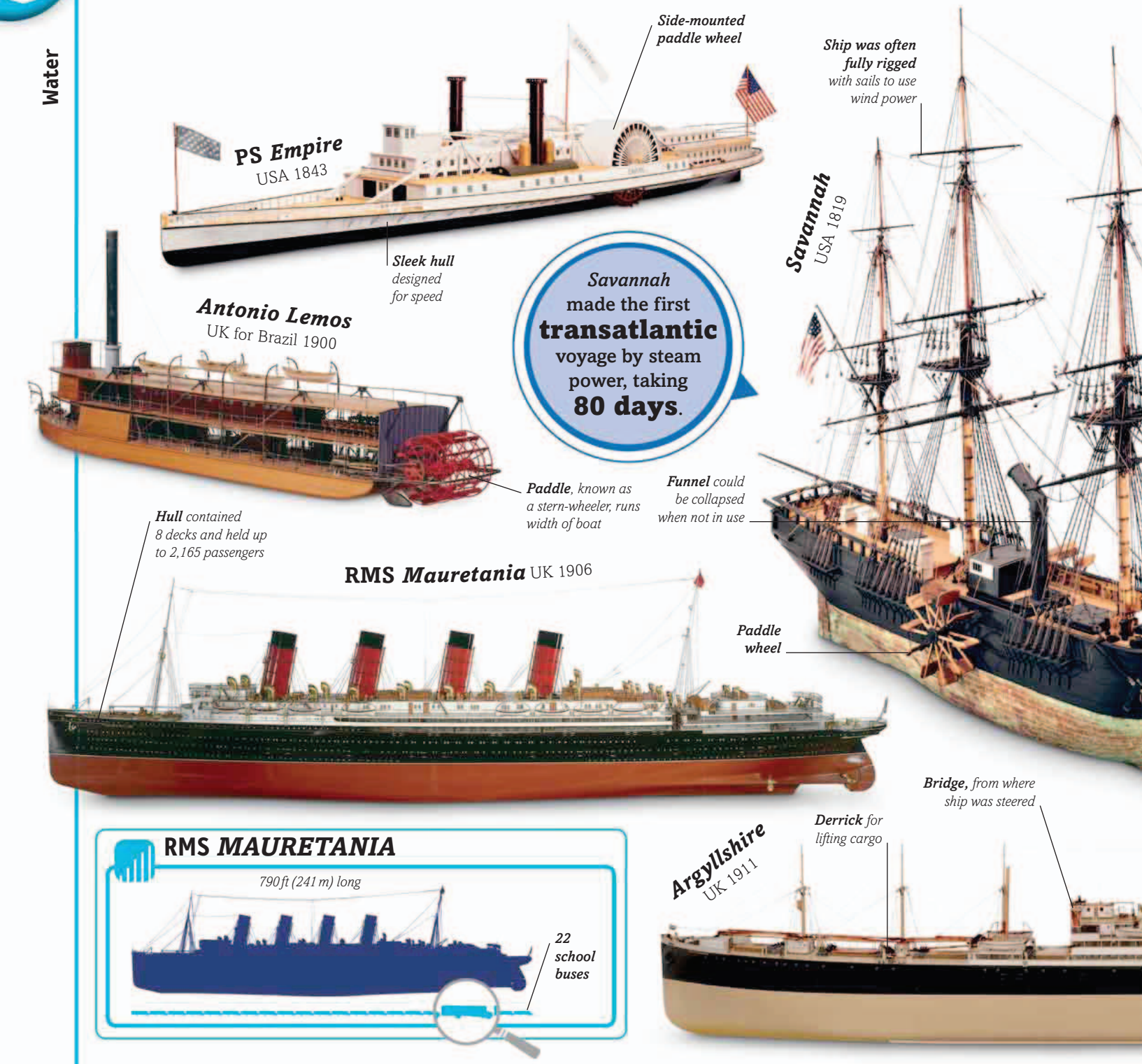
Helm

Lifeboat › There are seven lifeboats for 252 passengers and 130 crew.

First-class dining saloon and cabins

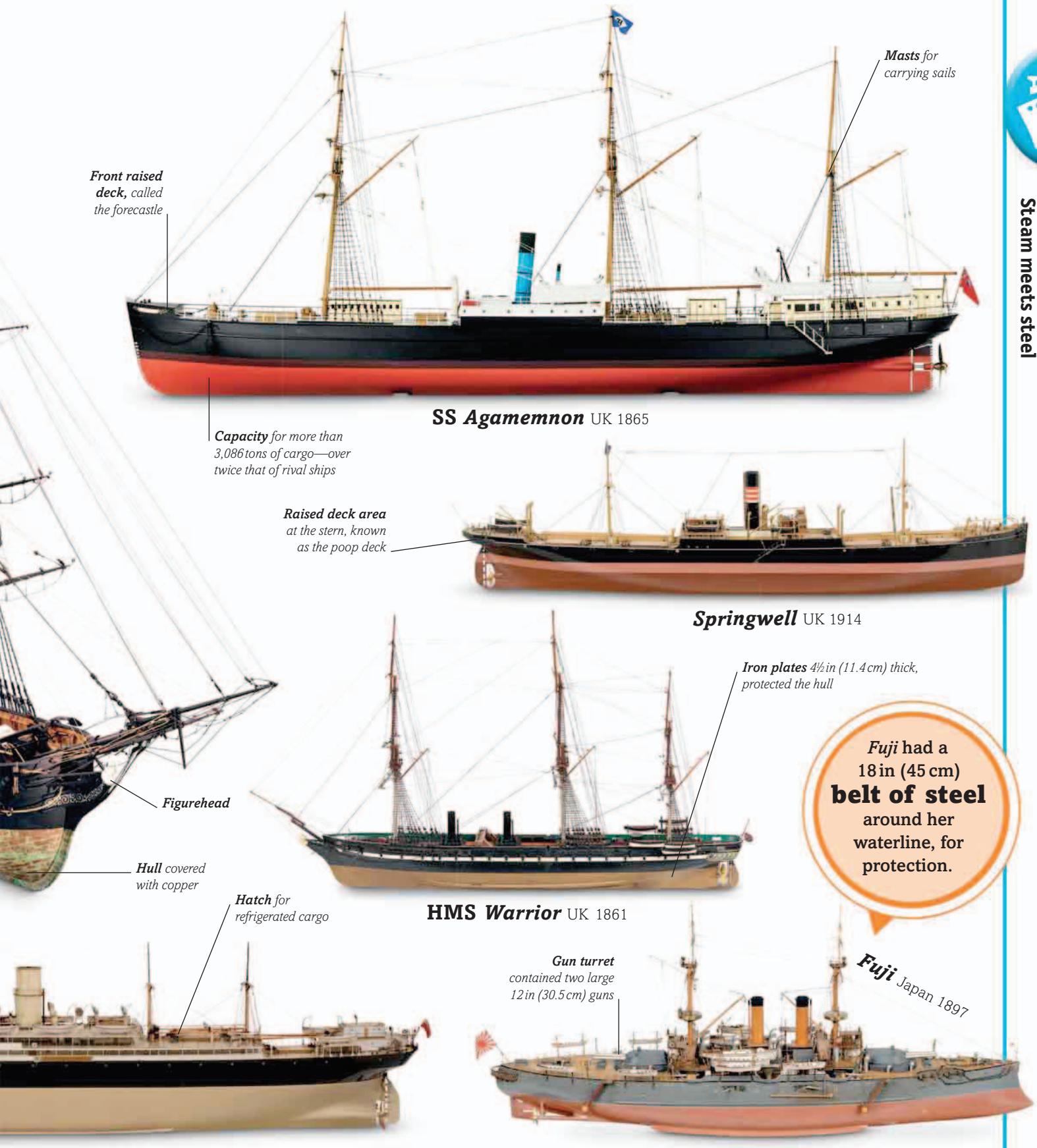
Propeller screw › The giant propeller has six blades and measures 16 ft (4.9 m) in diameter. As it turns, the propeller pushes water back, moving the ship forward.

Steam meets steel



The invention of the steam engine meant that ships no longer had to rely on the wind. When steam power was used to drive steel ships, the result was large, sturdy vessels that could travel greater distances faster than ever before.

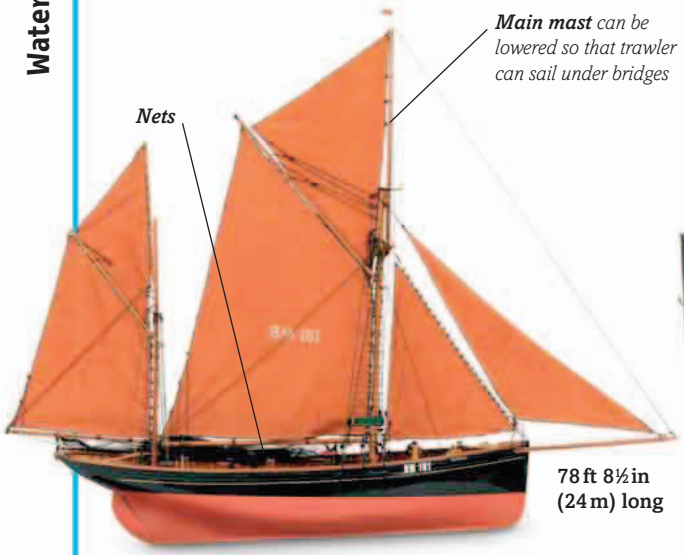
Early steamships could not hold much cargo because of the vast amounts of coal they needed to carry as fuel. The **SS *Agamemnon***, however, could run on just 22 tons of coal a day, allowing it to sail economically between Europe and the Far East. Powerful steam liners such as



Fuji **had a 18 in (45 cm) belt of steel around her waterline, for protection.**

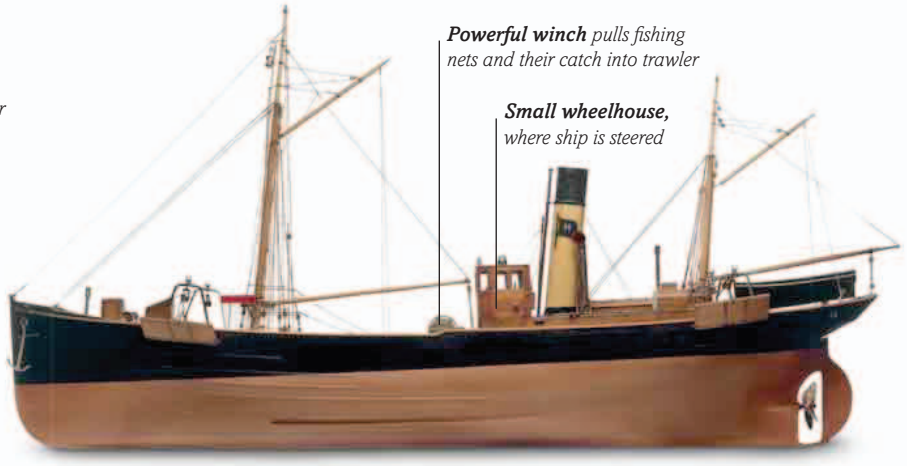
the **RMS *Mauretania***, were now able to cross the Atlantic in as little as four or five days. Early steamships, such as the **PS *Empire***, were mostly made of wood, but iron and steel hulls became more common. Steel made it possible to build refrigerated ships, such the ***Argyllshire***, which transported meat from South America and Australasia to Europe. Steel and steam were also adopted by navies. **HMS *Warrior*** was among the first Royal Navy ships to come with an iron hull and steel armor. It carried a crew of 706 as well as 40 giant artillery guns.

Working ships



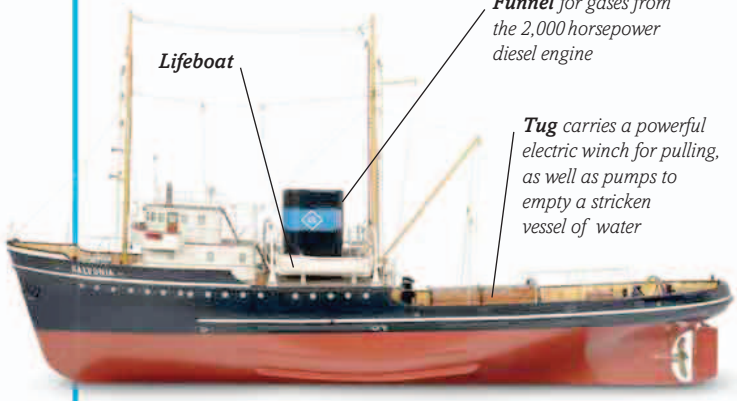
78 ft 8½ in (24 m) long

Sailing trawler *Valerian* UK 1923



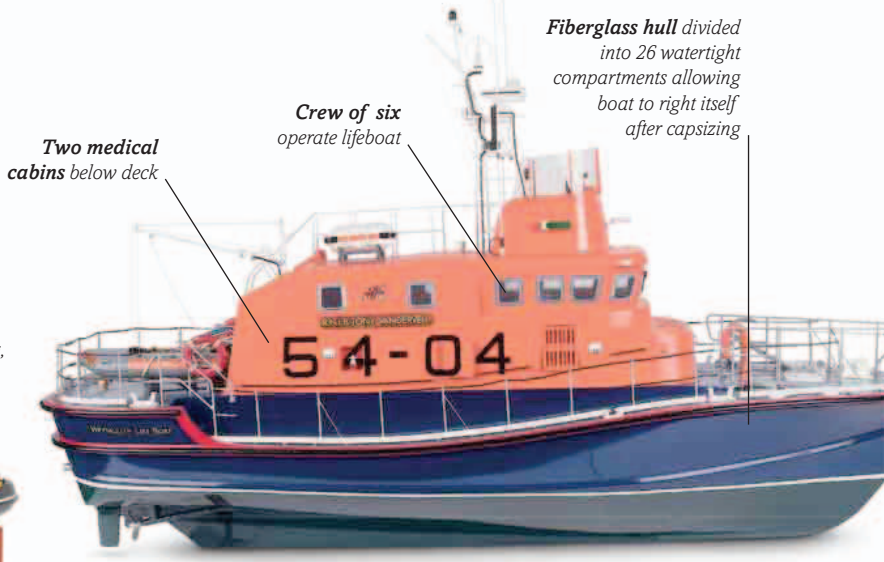
Steam trawler UK 20th century

108 ft ½ in (33 m) long



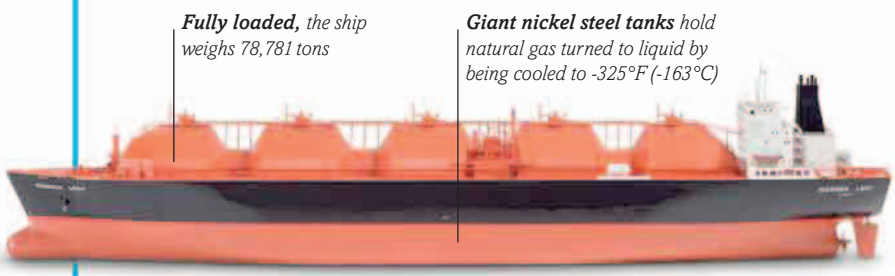
157 ft (48 m) long

Tug *Salvonia* Netherlands 1951



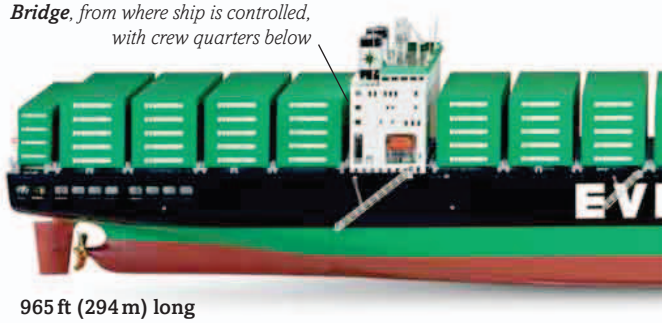
52 ft (16 m) long

Arun class lifeboat UK 1970s–1990s



817 ft (249 m) long

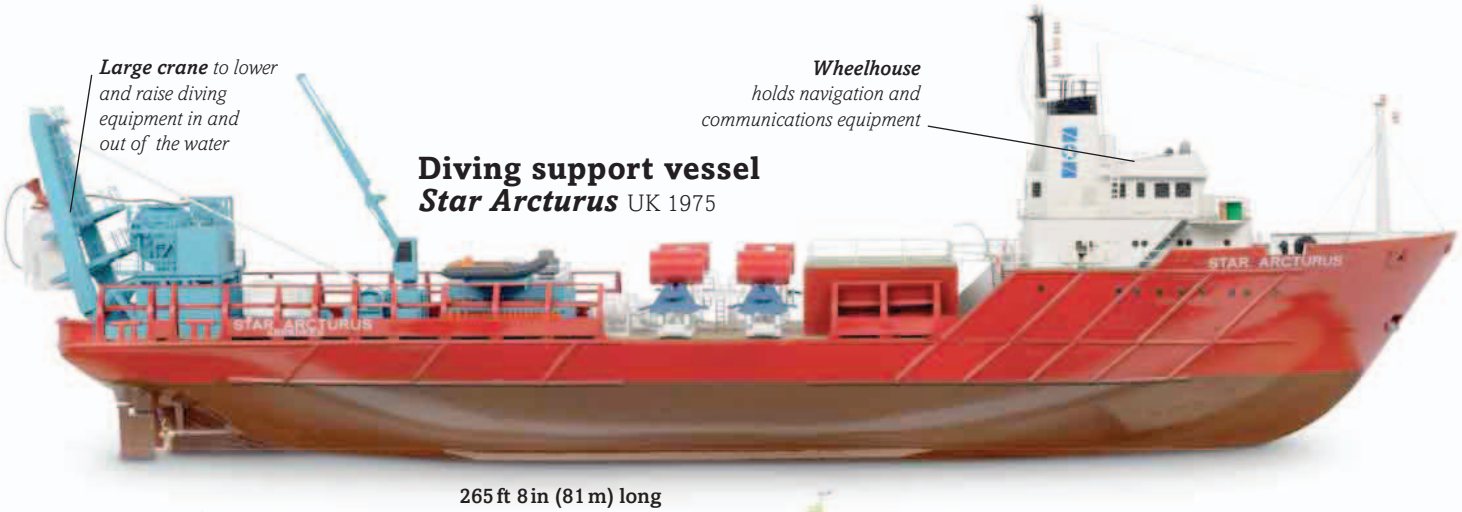
Gas carrier *Norman Lady* Norway 1973



965 ft (294 m) long

Every day, thousands of ships are at work in a variety of different ways. Many carry billions of tons of goods, fuel, and material across the waters of the world. Others save lives, assist other ships, and catch food from the seas and oceans.

Tankers carry liquids, such as oil or, in the case of ***Norman Lady***, liquefied natural gas. The ***Shin Aitoku Maru*** is an oil tanker with a difference. Its computer-controlled sails help it save fuel, which is used to power its diesel engines. The ***Ever Royal*** carries goods and



Diving support vessel *Star Arcturus* UK 1975

265 ft 8 in (81 m) long

Sailing tanker *Shin Aitoku Maru* Japan 1980

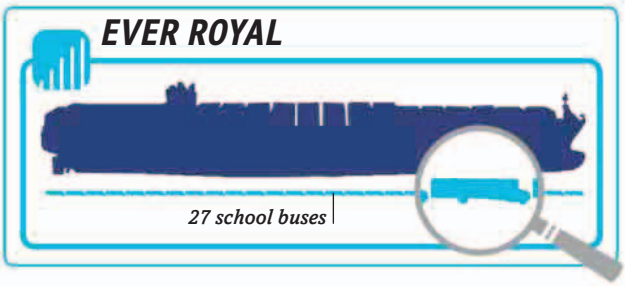
236 ft (72 m) long

Icebreaker *Otso* Finland 1985

324 ft 9½ in (99 m) long

Otso's powerful engines generate **15 million** watts of electricity!

Container ship *Ever Royal* Japan 1993



materials stored in up to 4,200 standard 20-ft- (6-m-) long containers, designed to be easily unloaded onto trucks. Some working ships help serve others. Icebreakers, such as ***Otso***, can plow through ice many meters thick to clear a path to let ships through. Other vessels act as tugs, such as the oceangoing ***Salvonia***, which can tow a stricken ship out of danger and home for repairs. Coastguards and other maritime rescue services operate boats like the **Arun class lifeboat**, which can travel through the stormiest of waters to rescue people at sea.

Passenger carriers

The *Titanic* had a **kennel for dogs** of first-class passengers, and its own daily newspaper.

RMS *Titanic* UK 1911

883 ft (269 m) long

Funnel *channels smoke from the ship's 29 boilers*

False funnel *where pets were housed*

Normandie France 1932

Promenade deck

Children's playroom and gymnasium

1,029 ft (313.8 m) long

Cargo derrick *for loading and unloading cargo from hull*

Radio antenna *strung between two masts*

Mast *rises more than 164 ft (50 m) above water and holds powerful horns*

Twin propellers *give a speed of 26 mph (41.7 km/h)*

America USA 1939

723 ft (220.4 m) long

Bridge, *from where the ship is navigated*

Passenger cabins *with balconies overlooking the sea*

948 ft (289 m) long

Grand Princess Italy for USA 1998

Queen Elizabeth 2 UK 1969

965 ft (294 m) long

Every year, hundreds of millions of people travel on ships for work or pleasure. Many use ferry services, linking places separated by water. Others cruise aboard large passenger liners, traveling the seas and oceans of the world.

Water taxis, such as Tokyo's ***Himiko*** **water bus**, transport people short distances, while larger ferries like the ***Arcturus*** move people and their vehicles across lakes and seas. The **MDV 1200 Class ferry** has capacity for 175 cars and more than 600 passengers. The ***America*** liner held

509 ft (155 m) long

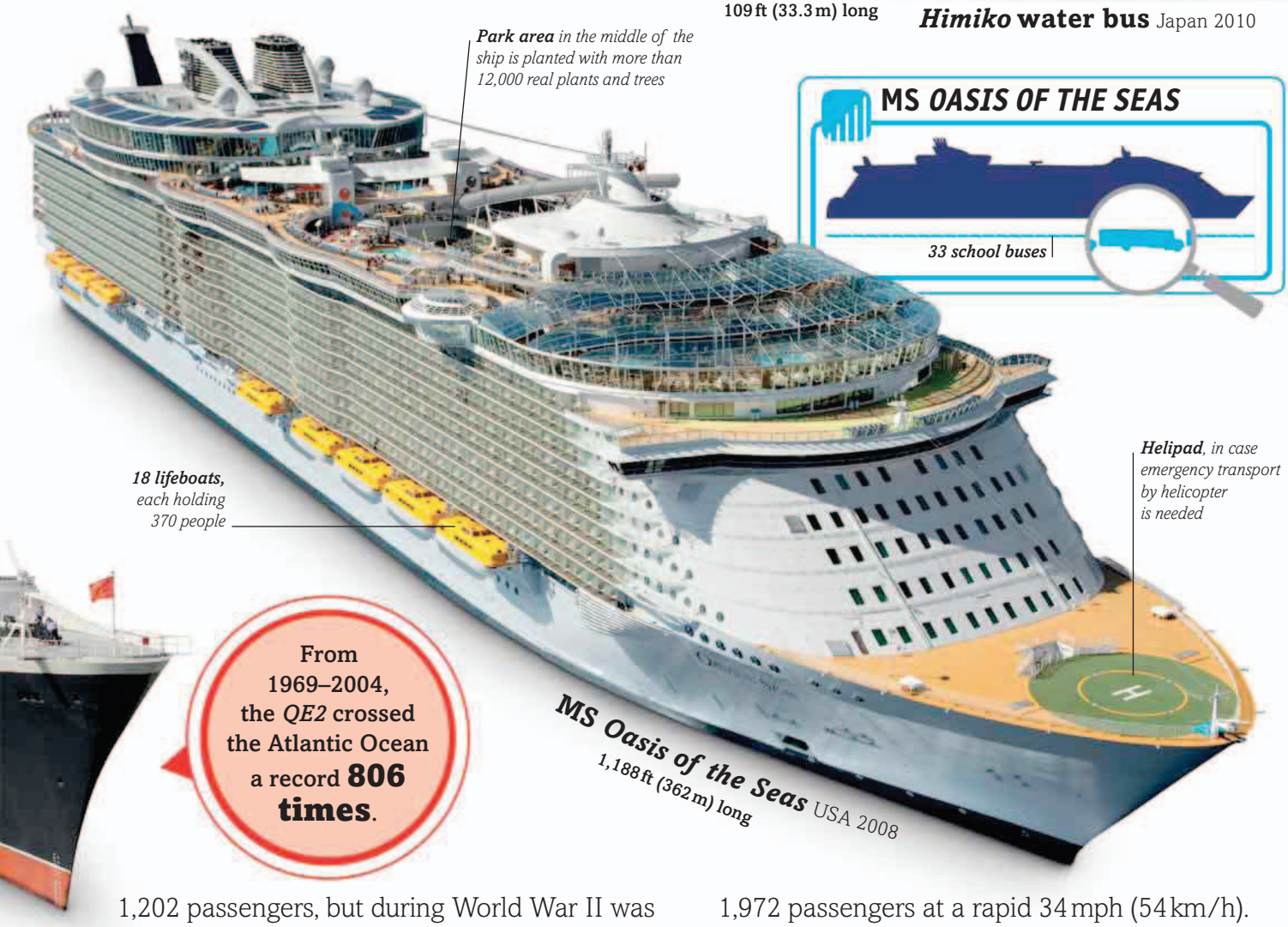
Ro-ro ferry *Arcturus* Finland 1982

328 ft (100 m) long

MDV 1200 Class ferry Italy 1990s

109 ft (33.3 m) long

***Himiko* water bus** Japan 2010



MS *Oasis of the Seas* USA 2008

1,188 ft (362 m) long

From 1969–2004, the *QE2* crossed the Atlantic Ocean a record **806 times**.

1,202 passengers, but during World War II was converted into a troop ship carrying 7,678 soldiers. Over the years, even bigger passenger liners were launched, including the **RMS *Titanic***, which sank on its maiden voyage in 1912, and the ***Normandie***, which could carry 1,972 passengers at a rapid 34 mph (54 km/h). With 17 decks carrying up to 3,600 passengers, the ***Grand Princess*** became the world's largest liner, until overtaken by the gigantic **MS *Oasis of the Seas***, which, at 248,330 tons, weighs almost five times as much as the *Titanic*.

CITY ON THE SEA The world's biggest cruise ship, Royal Caribbean International's *Allure of the Seas,* enters her home harbor of Port Everglades, Florida, in 2010. This gigantic, 16-deck floating hotel is almost as long as four football fields, and houses up to 6,318 guests who are looked after by a crew of 2,384 people. It's almost as if a small floating city has taken to the water.

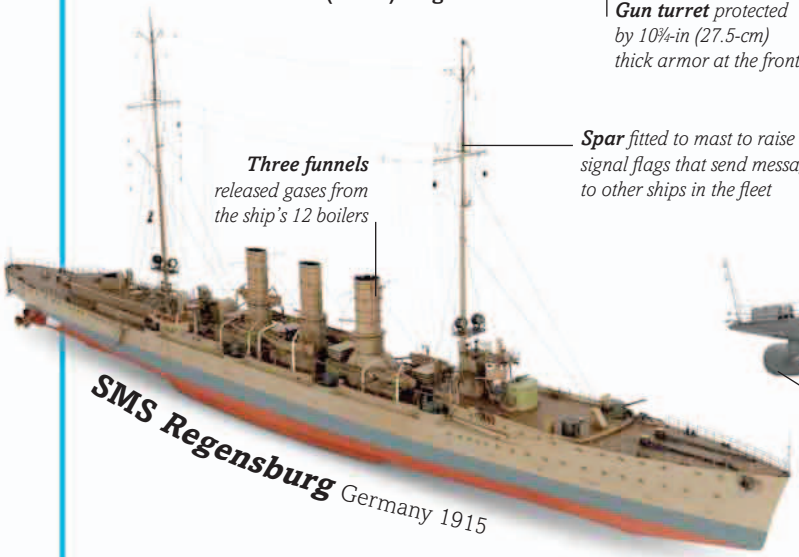
Built in Finland between 2008 and 2010, this gigantic vessel is 1,188 ft (362 m) long. She rises to 236 ft (72 m) above the waterline, but her funnels can telescope down for passing under low bridges. The liner's many attractions include 25 restaurants, a 1,380-seat theater, a full-size basketball court, a rock climbing wall, 21 swimming pools and jacuzzis, and wave machines that pump out more than 58,000 gallons (220,000 liters) of water a minute, so people can surf as they cruise! There's even a 2,230-ft- (680-m-) long running track, and a park area with thousands of real plants and trees. The 248,330-ton ship cruises the Caribbean or Mediterranean Sea at the stately speed of 26 mph (42 km/h).

World War ships

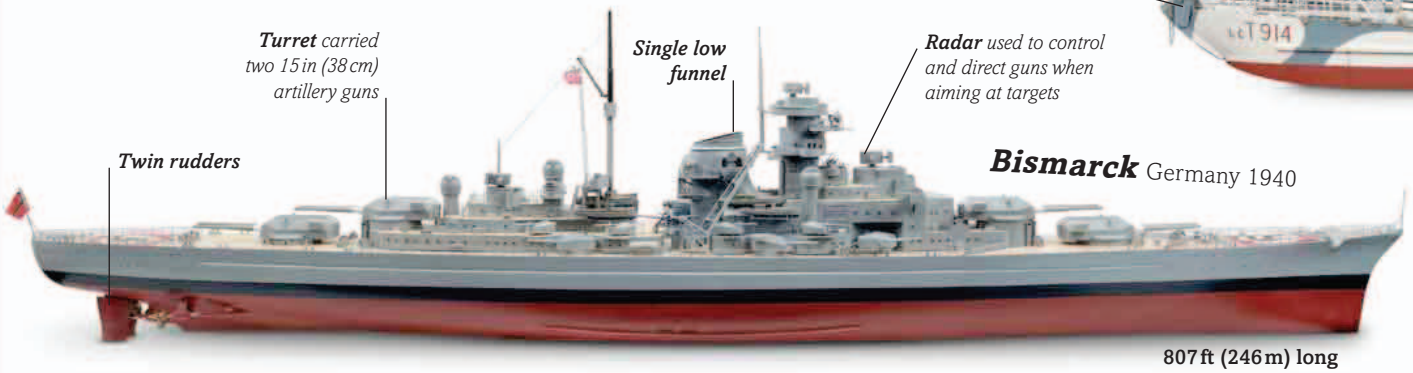
778 ft (237 m) long

535 ft (163 m) long

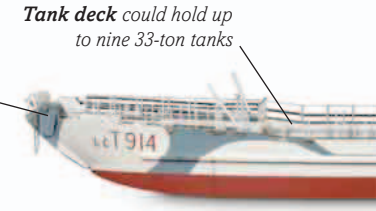
The *Yamato's* **giant guns** could fire shells at targets **26 miles** (42 km) away.



466 ft (142 m) long

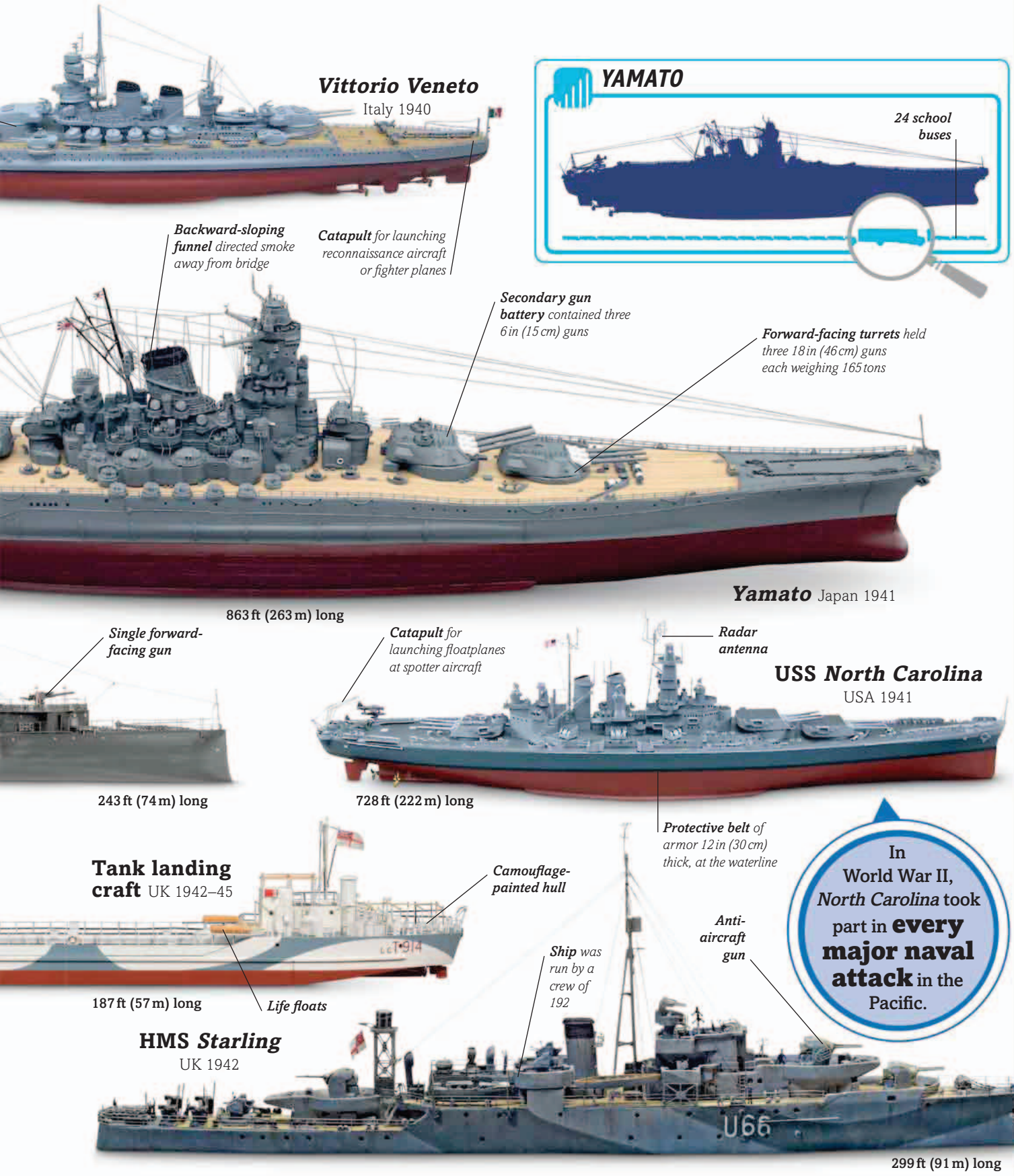


807 ft (246 m) long



Shipping played a crucial part in both World War I and World War II. As well as fighting in battles, warships were used to disrupt enemy supply convoys, protect their own navies, and transport troops and equipment to invade enemy territory.

HMS *Dreadnought* was faster and more heavily armed than previous battleships and started an arms race between the major naval powers before World War I. Smaller ships, such as the cruiser **SMS *Regensburg***, and the **P34 patrol boat**, saw active service during WWI. P34 was



In World War II, *North Carolina* took part in **every major naval attack** in the Pacific.

one of the first dedicated antisubmarine vessels. **HMS *Starling*** performed a similar role during World War II, sinking 14 German U-boats. The ***Bismarck*** was Germany's biggest battleship, until it was sunk in 1941. Biggest of all was the ***Yamato***, at over 77,161 tons. It was heavily armed, with nine giant guns, dozens of smaller artillery weapons, and 162 antiaircraft guns. It cruised the Pacific with a range of 8,264 miles (13,300 km). **Tank landing craft** had a tenth of that range, but were crucial in ferrying tanks during the Normandy landings.

Aircraft carriers

Nuclear reactors can keep USS *George Washington* running for **18 years**, with no need to refuel!

Gases from funnel *could create difficult air currents for landing aircraft*

Up to 36 biplanes *could be carried*

Elevator *raises planes stored below onto flight deck*

786 ft 5 in (239.7 m) long

Hangar *for aircraft storage*

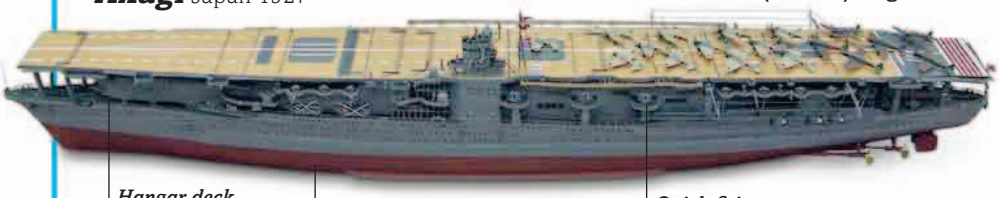
HMS *Furious* UK 1917

Missile launcher

Four propellers *move the carrier at speeds up to 35 mph (56 km/h)*

855 ft 4 in (260.7 m) long

Akagi Japan 1927



Hangar deck *on two levels*

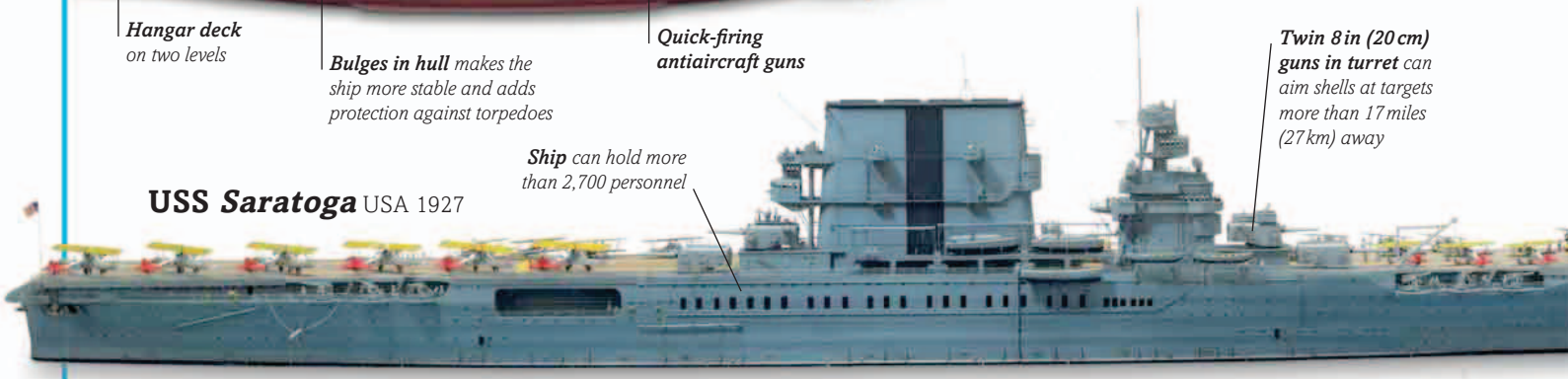
Bulges in hull *makes the ship more stable and adds protection against torpedoes*

Quick-firing antiaircraft guns

Twin 8 in (20 cm) guns in turret *can aim shells at targets more than 17 miles (27 km) away*

Ship *can hold more than 2,700 personnel*

USS *Saratoga* USA 1927



888 ft (270.7 m) long

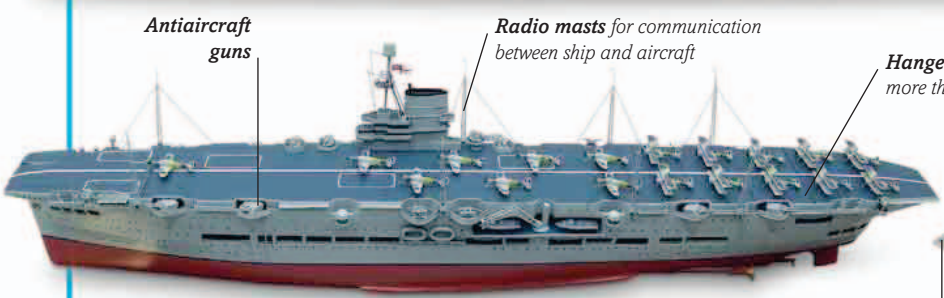
Antiaircraft guns

Radio masts *for communication between ship and aircraft*

Hangers *could hold more than 60 aircraft*

Aircraft *parked on armored flight deck*

HMS *Illustrious*
UK 1940



800 ft (243.8 m) long

HMS *Ark Royal* UK 1938

Flight deck *ended in "round down" to reduce air turbulence for planes taking off*

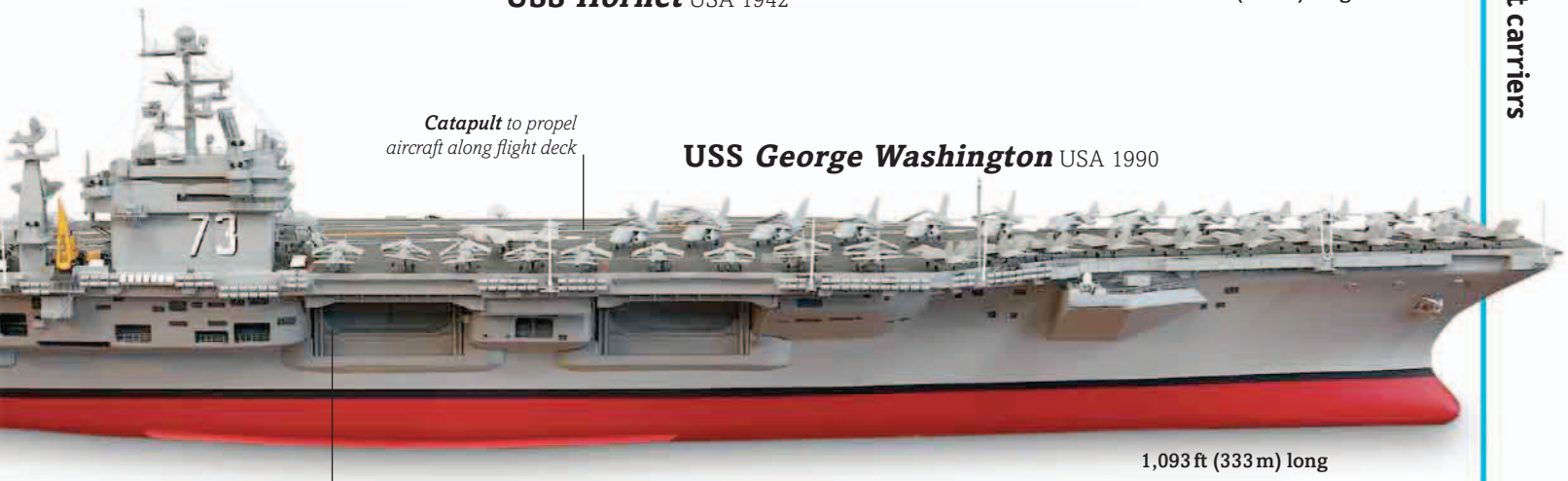
751 ft (229 m) long

As aircraft became important military weapons, ships that could act as floating airbases were designed. These aircraft carriers are huge vessels with a large, flat flight deck, from which helicopters and planes can take off and land.

Many early aircraft carriers, including the **USS *Saratoga***, **HMS *Furious***, and the ***Akagi*,** were initially designed as battle cruisers before being converted. The *Akagi* carried up to 66 aircraft, which took off from three flight decks, while the *Saratoga* could carry up to 78 planes. Specially

USS *Hornet* USA 1942

873 ft (266 m) long

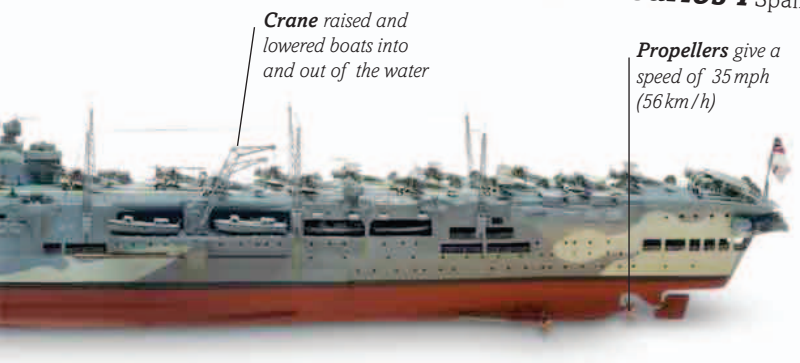


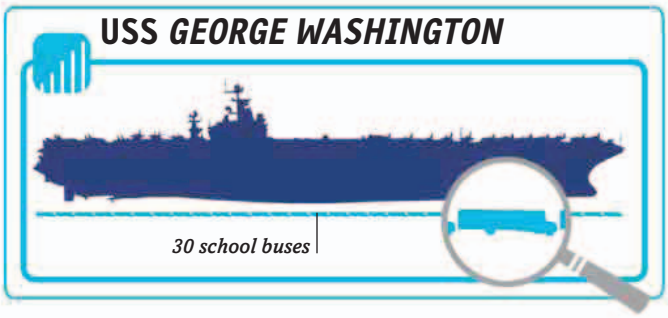
USS *George Washington* USA 1990

1,093 ft (333 m) long

Juan Carlos I Spain 2003

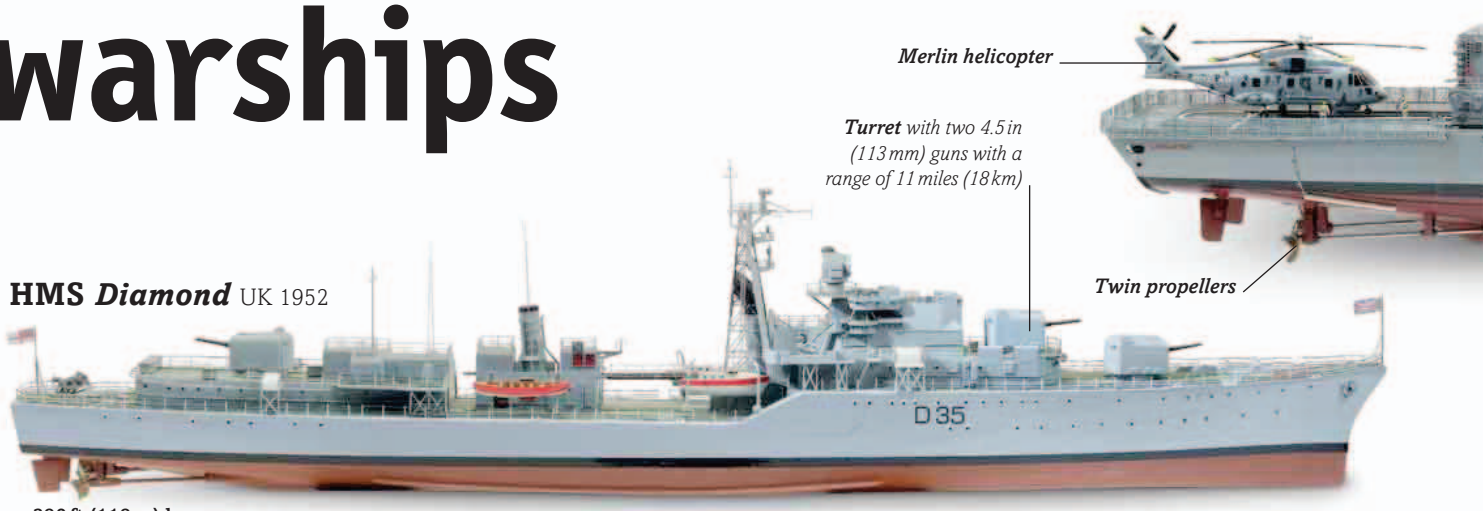
757 ft (230.8 m) long





built aircraft carriers, such as **HMS *Illustrious*** and the **USS *Hornet***, featured catapults powered by hydraulics or steam to propel the aircraft on takeoff, as well as hangers below the flight deck to store inactive planes. Aircraft carriers have large crews—1,580 in the case of **HMS *Ark Royal***. However, this figure is dwarfed by the more than 6,000 who serve aboard the Nimitz Class carrier, **USS *George Washington***. This 97,003-ton ship holds up to 90 aircraft of varying types, from reconnaissance planes and helicopters to fighters and bombers.

Modern warships



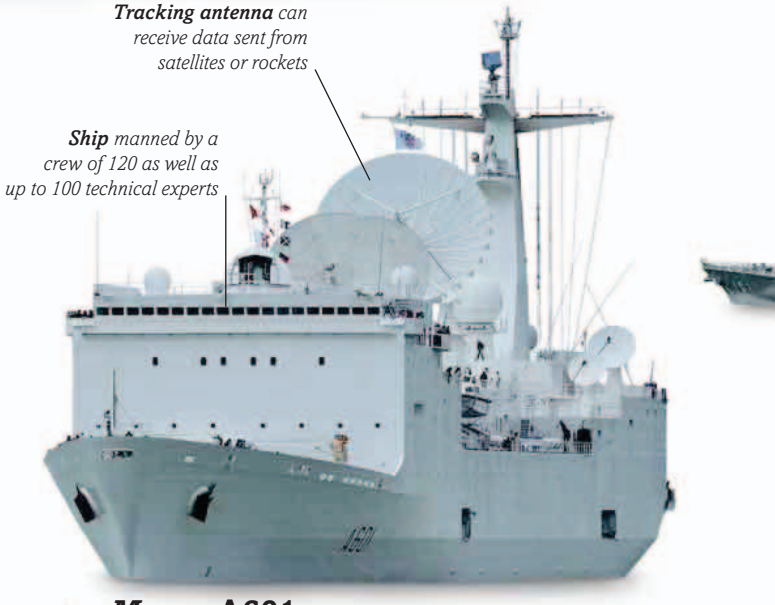
HMS *Diamond* UK 1952

390 ft (119 m) long

151 ft (46 m) long

HMS *Kirkliston*
UK 1954

Twin propellers powered by diesel engine



***Monge* A601** France 1990

738 ft (225 m) long

The ship's Tomahawk missiles have a range of more than **800 miles** (1,300 km).

USS *Arleigh Burke*
USA 1991

505 ft (154 m) long

Aircraft carriers and nuclear submarines have taken over from battleships as the biggest and most lethal craft in a navy's fleet. Yet there remains plenty of work for smaller ships, which are built to perform a wide variety of important roles.

Frigates like **HMS *Lancaster*** and **HMCS *Vancouver*** are multipurpose—able to protect and escort other ships, perform coastal patrols, intercept suspicious ships, and engage in antisubmarine warfare. The **USS *Arleigh Burke*** destroyer also tackles submarines, as well as

HMS *Lancaster* UK 1992 **436 ft (133 m) long**

440 ft (134 m) long **HMCS *Vancouver*** Canada 1993

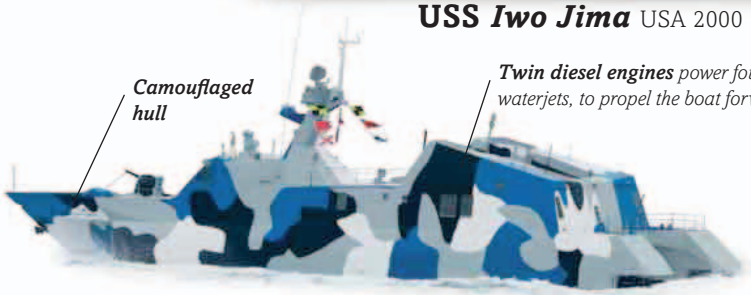
331 ft (101 m) long **Elbe class** Germany 1993

495 ft (151 m) long

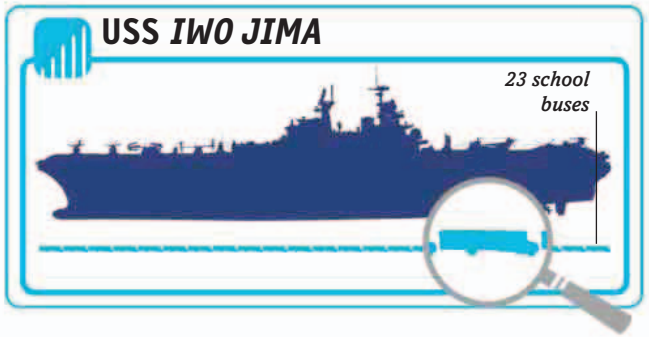
Murasame class destroyers Japan 1994

843 ft (257 m) long

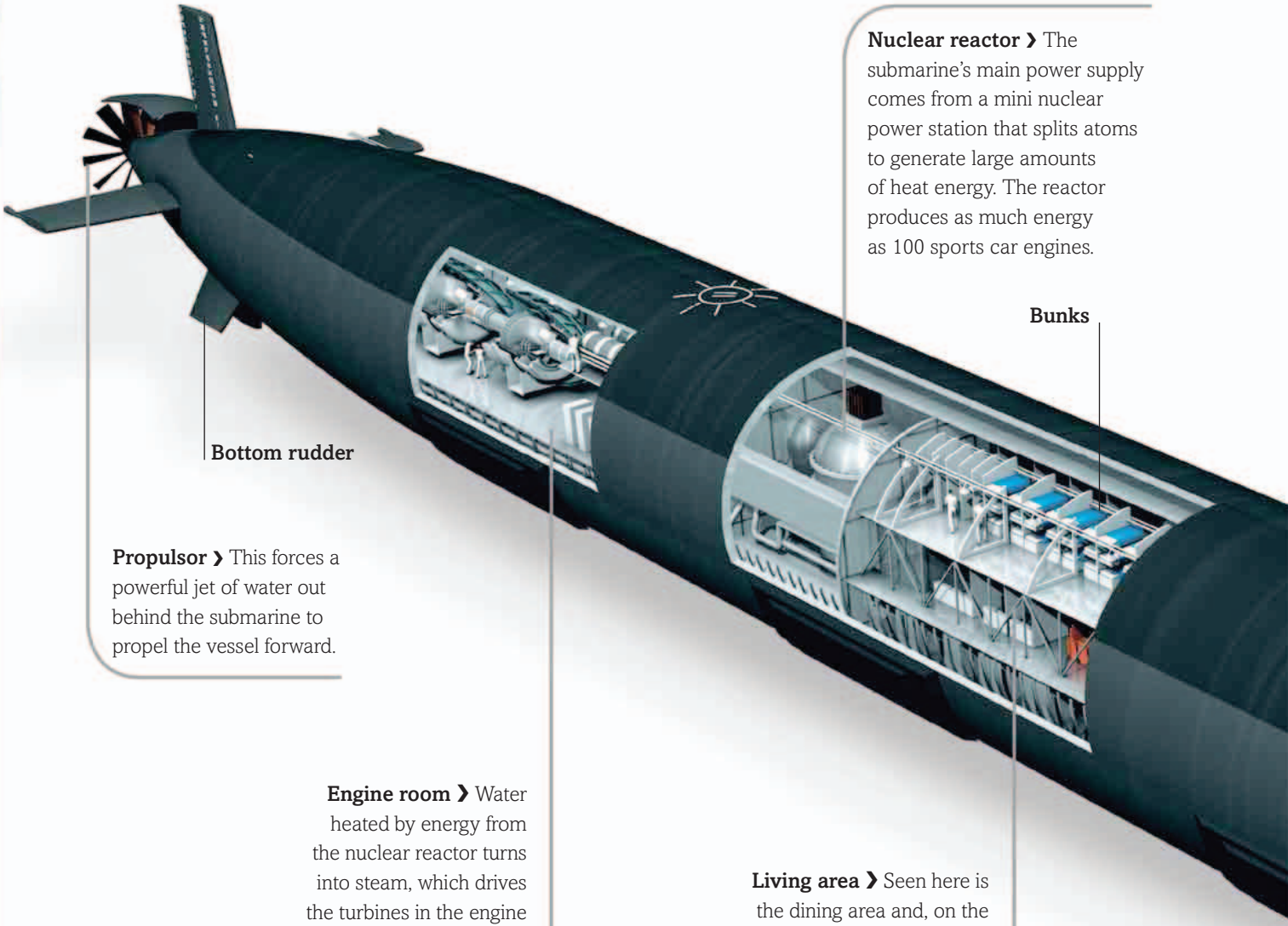
USS *Iwo Jima* USA 2000



Type 022 missile boat China 2004 **138 ft (42 m) long**



attacking other targets at sea or on land, using guided missiles. Some warships have highly specialized roles. **HMS *Kirkliston*** swept for mines laid in shallow coastal waters. The ***Monge*** **A601** monitors the skies, using its 14 antennae and other electronic systems to track missiles and space missions. The **Type 022 missile boat** can creep under enemy warning systems to launch attacks on shipping, while the **USS *Iwo Jima*** supports missions onshore, carrying just short of 1,900 marines, up to 30 helicopters, and large numbers of amphibious landing craft.



Nuclear reactor › The submarine's main power supply comes from a mini nuclear power station that splits atoms to generate large amounts of heat energy. The reactor produces as much energy as 100 sports car engines.

Bunks

Bottom rudder

Propulsor › This forces a powerful jet of water out behind the submarine to propel the vessel forward.

Engine room › Water heated by energy from the nuclear reactor turns into steam, which drives the turbines in the engine room. The turbines, in turn, power the propulsor.

Living area › Seen here is the dining area and, on the floor above, the bunk beds. The crew of 134 may spend three months at sea, so there is a gym and a movie theater to keep them entertained.

Submarine

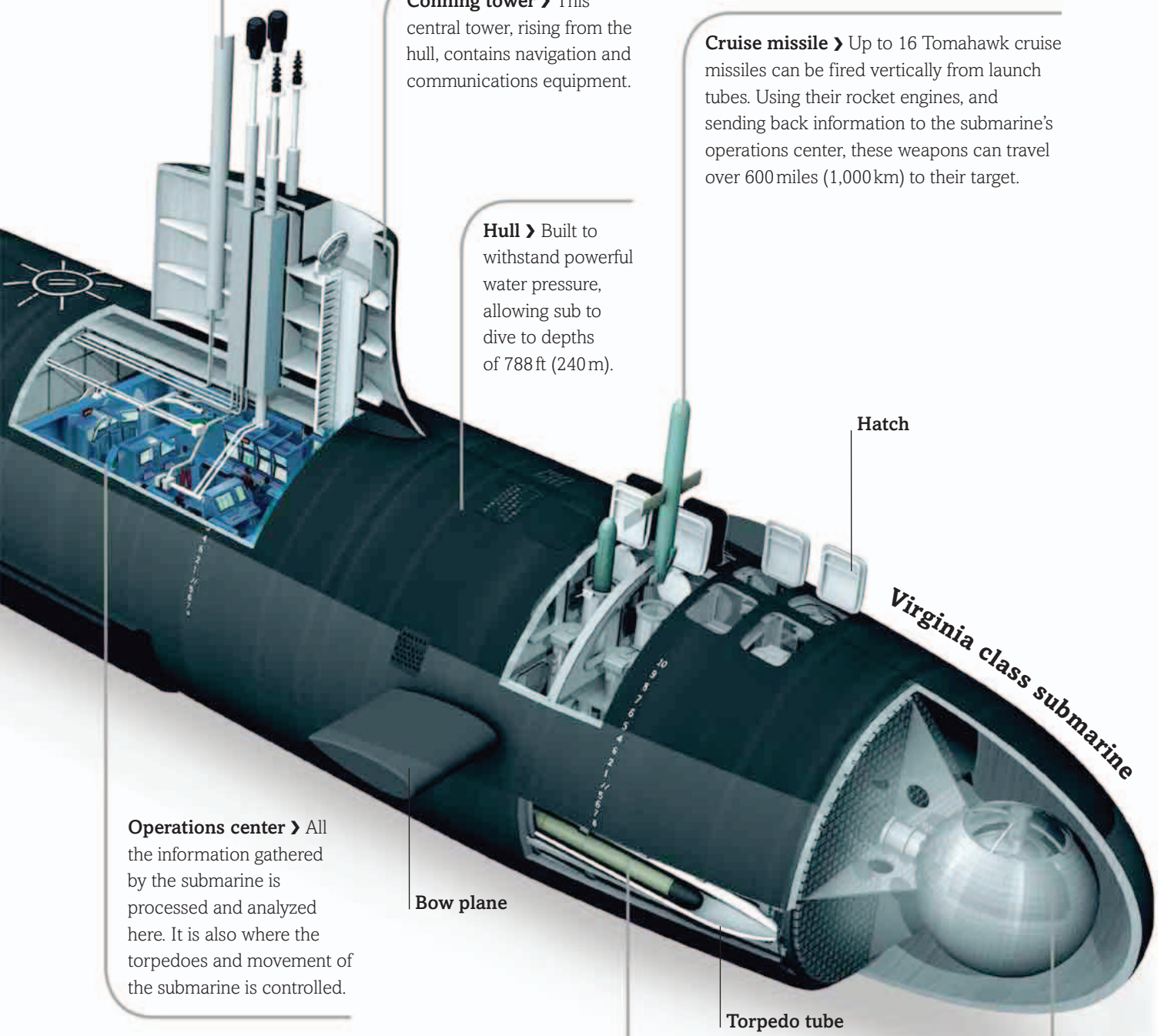
Submarines can adjust their buoyancy (how much they can float or sink) using large ballast tanks that can be filled with air or seawater. These tanks allow submarines to dive deep below sea level, cruise stealthily underwater, or rise to the surface. The 377-ft- (115-m-) long **Virginia class submarine** serves in the US Navy. Packed with advanced systems, each submarine took around nine million working hours to build.

Masts › These carry radio and global positioning antennae, and a mast that allows the crew to see above the surface using night vision and a zoom lens.

Conning tower › This central tower, rising from the hull, contains navigation and communications equipment.

Cruise missile › Up to 16 Tomahawk cruise missiles can be fired vertically from launch tubes. Using their rocket engines, and sending back information to the submarine's operations center, these weapons can travel over 600 miles (1,000 km) to their target.

Hull › Built to withstand powerful water pressure, allowing sub to dive to depths of 788 ft (240 m).

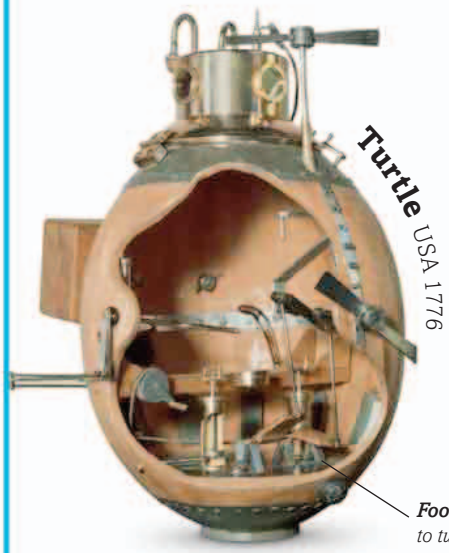


Operations center › All the information gathered by the submarine is processed and analyzed here. It is also where the torpedoes and movement of the submarine is controlled.

Torpedo › These are the standard weapons of most military submarines. Launched from tubes, they travel to their target using built-in engines. The Virginia class uses Mk48 torpedoes, which each weigh 3,435 lb (1,558 kg) and carry 650 lb (295 kg) of explosives.

Sonar sphere › This helps the submarine navigate through the water, by sending out sound waves to measure the distance of objects.

Dive, dive, dive



Turtle USA 1776

6 ft (1.8 m) tall

Foot pedals *used to turn the propeller*

Three Aichi M6A *were stored in, and launched, from this submarine*

Access hatch

64 ft (19.5 m) long

HMS Holland No. 1 UK 1901

Propeller *gives a top speed of 9 mph (15 km/h) when submerged*

U-9 Germany 1910

188 ft 3 in (57.4 m) long

3/4 in (2 cm) cannon

Torpedo tubes *fired the submarine's 14 torpedoes, to sink enemy ships*

220 ft (77 m) long

Type VIIC Germany 1940

Pressurized hull *provides living and working space for crew of 60*

Covered propeller *reduces the sound, making the submarine harder to detect*

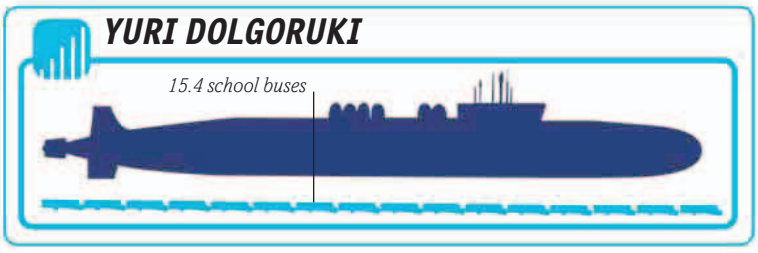
USS Gato USA 1941

Bow torpedo tubes

311 ft 7 in (95 m) long

Stern torpedo tubes

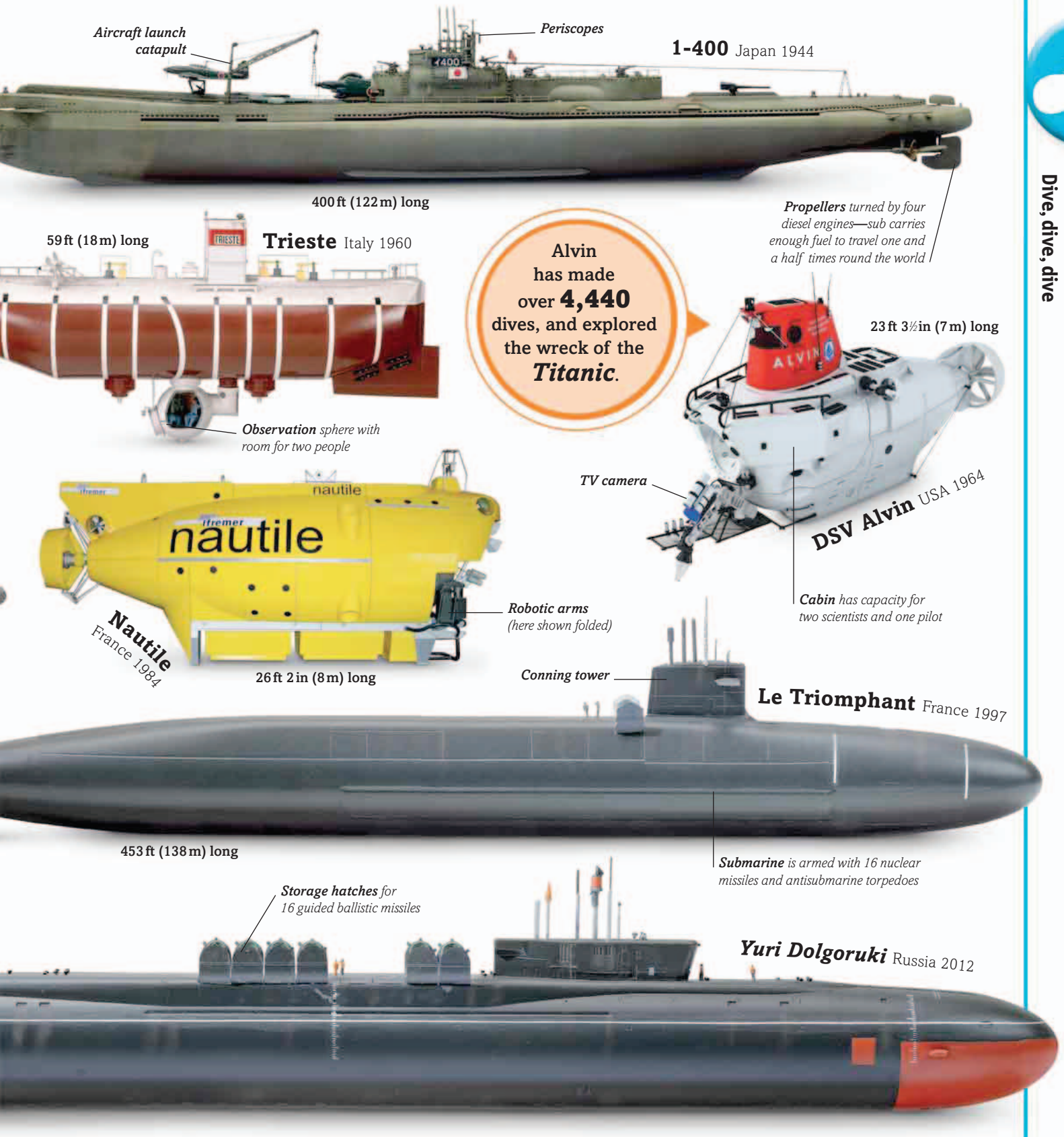
Top rudder *helps steer the submarine*



558 ft (170 m) long

With their ability to lurk beneath the waves for weeks at a time, submarines are a potentially deadly underwater weapon. Submersibles are much smaller vessels, used for underwater scientific research, and rescue and salvage work.

The **Turtle** was the first sub to see action, when it attempted to place explosives on the hulls of enemy ships during the Civil War. It was not until World War I that subs became effective in warfare. The German **U-9** sank 16 ships, and the **Type VIIC** U-boat reached depths of 500 ft



(150 m). The **USS Gato** could travel up to 12,500 miles (20,000 km) on patrols, while **1-400** class submarines, the largest of World War II, could launch aircraft from their decks. Nuclear energy gave modern submarines like **Le Triomphant** and ***Yuri Dolgoruki*** limitless power, allowing them to patrol for months at a time. Small research submersibles have limited range, but can perform amazing feats. **DSV Alvin** can dive to 21,000 ft (6,400 m), while **Trieste** carried people to the deepest part of the Pacific Ocean, 35,797 ft (10,911 m) below sea level.

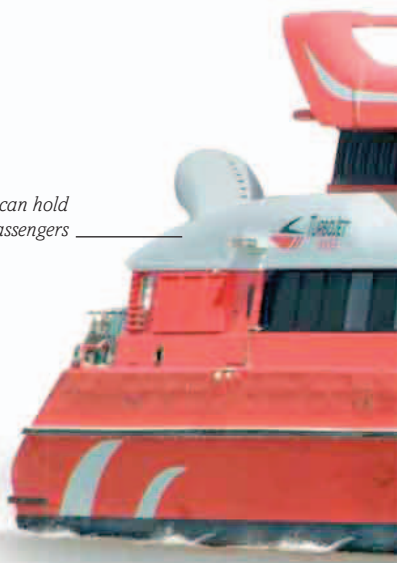
Need for speed

BHC AP1-88 Hovercraft
UK 1990s

Navigation and communications antennae

Rubber skirt *is filled with air by fans under the body of the hovercraft*

This craft is used by the Canadian Coastguard



Large cabin *can hold 190–243 passengers*

Capacity *for up to 30 cars, which enter craft using a ramp at the back*

SR.N4 Mk.I Hovercraft UK 1968

Voskhod 352 Eurofoil
Russia 1973

Railings *for observers on the roof of the cabin*

Six-bladed fan *propels craft at speeds up to 43 mph (70 km/h)*

Windshield *of cockpit, which seats 3 to 4*

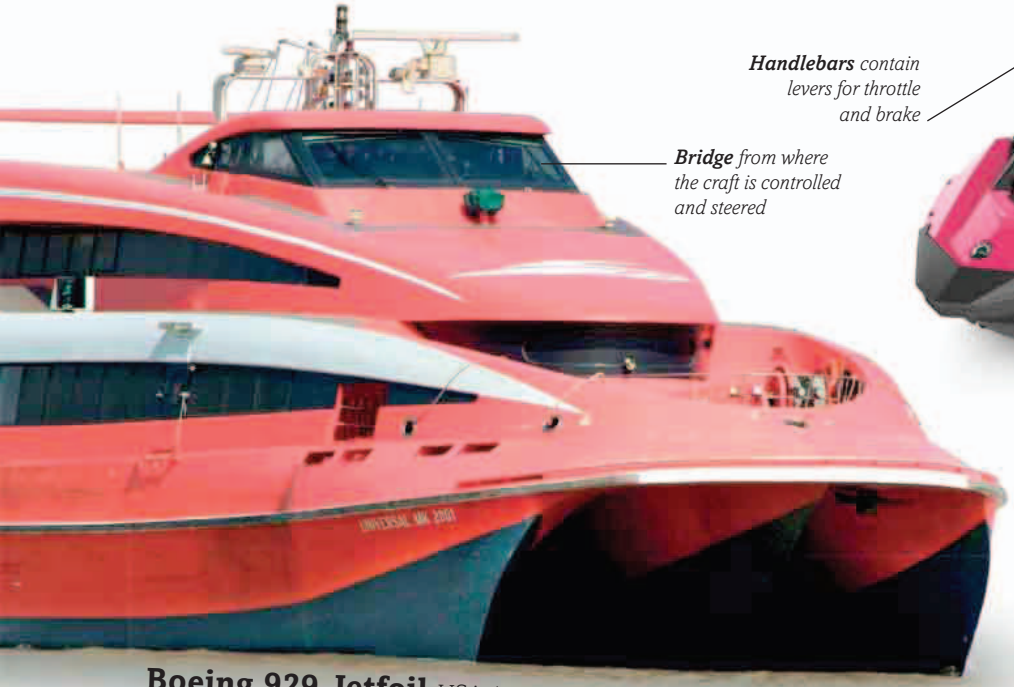
Skirt, *made up of 68 sections, keeps the craft on a cushion of air*

BHC Coastal Pro Hovercraft UK 2015

Military *Zubr*-class hovercraft are the world's **biggest** and can carry up to **500 troops**.

Some vessels don't travel through water, they skim the surface, so that most of their hull, or body, rides above it. This means they can travel faster. Surface-skimming craft, such as hovercrafts and hydrofoils, are definitely fast movers!

A hovercraft rides on a cushion of air generated by lift fans under their bodies, which enables it to travel over both land and water. The **SR.N4 Mk.I Hovercraft** could hold 254 passengers and cruise at over 60 mph (100 km/h), while the **BHC AP1-88 Hovercraft** was used by the



Bridge *from where the craft is controlled and steered*

Boeing 929 Jetfoil USA 1974

Handlebars *contain levers for throttle and brake*

Sea-Doo® Spark™ Canada 2013

The K7 set a world water speed record of 276 mph (444 km/h) in 1964.

Perspex canopy *covers cockpit*

Smooth aluminum body *fitted over a steel frame*

Bluebird K7 UK 1955

Handlebars *contain sound system and speakers*

Kawasaki Ultra 310LX Japan 2015

V-shaped hull *allows craft to travel smoothly through choppy water*

Rearview mirror

Sleek, streamlined body design *fashioned out of light but strong carbon fiber*

Catamaran hull *design with two floating hulls*

F1 Powerboat USA 2014

Canadian Coastguard for rescue missions. Hydrofoils, such as the **Voskhod 352 Eurofoil**, use wing-like foils under the hull to lift the boat out of the water as it travels forward. Jetfoils are hydrofoils that use water jets to provide their forward thrust, such as the **Boeing 929 Jetfoil**, which has a top speed of 50 mph (80 km/h). Personal watercraft, like the **Sea-Doo® Spark™** and the **Kawasaki Ultra 310LX,** also use water thrusters, while the fastest boats of all, **F1 Powerboats**, use propellers driven by powerful engines to race at over 125 mph (200 km/h).

Fun and games

Inboard motor *at the back of the boat spins propeller to move boat forward*

Motorboat USA 1950s

Inflatable body, *7 ft 2½ in (2.2 m) long, takes less than 90 seconds to inflate*

Wilderness raft USA

Mooring ring

Safety helmets *must be worn as well as life jackets*

Whitewater dinghy USA

1,200 inflatable dinghies paddled down the Aar River in Switzerland in 2011.

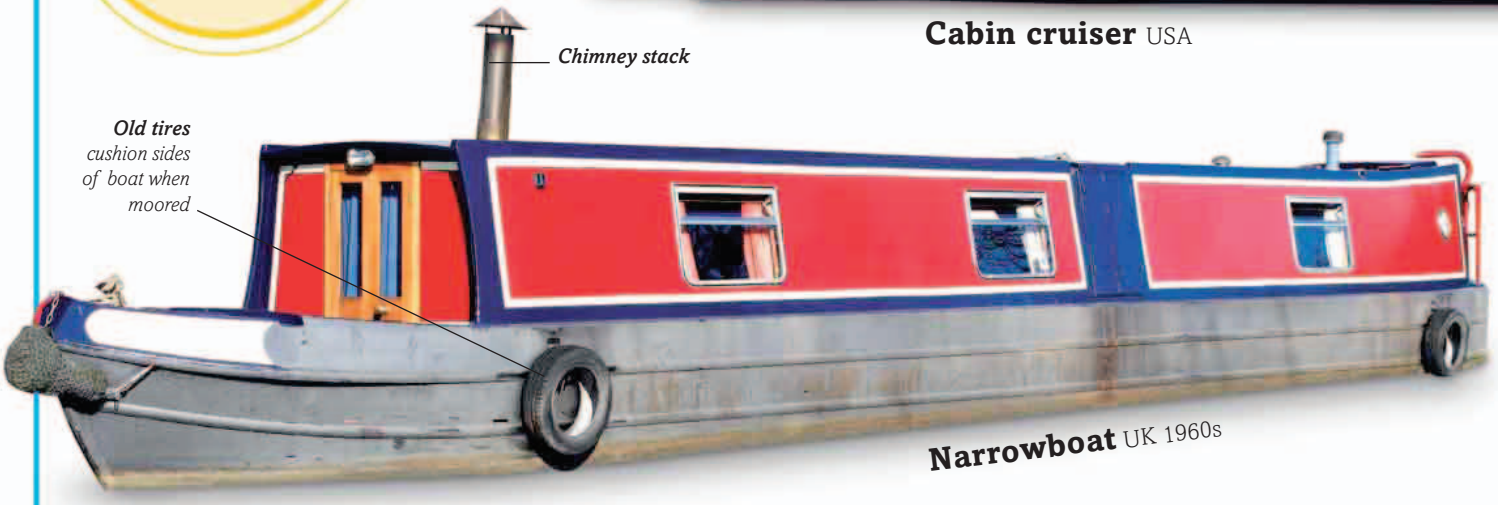
Twin hulls *make this a catamaran-style cabin cruiser*

Flexible cover *can be removed in good weather*

Cabin cruiser USA

Chimney stack

Old tires *cushion sides of boat when moored*



Narrowboat UK 1960s

There is nothing like having fun on the water! Plenty of different boats and watercraft of all shapes and sizes allow people to have fun on rivers, lakes, and seas, to explore wildernesses, and to take part in races and competitions.

A **wilderness raft** is a type of inflatable dinghy that is small and light enough to be carried in a backpack—before it is filled with air. Rugged **whitewater dinghies** are larger and ride down rapids and fast-flowing water. Paddles are used in **canoes** and **kayaks**, while a **rowboat** has

oars, which pivot in fixtures called oarlocks as they are rowed back and forth. **Sailing dinghies** are used to teach people how to sail, while **airboats** offer thrilling rides, speeding along with the help of large fans spun by car or aircraft engines. **Narrowboats** were once used to haul coal, cotton, and other goods along canals before there were train and road networks; today, they are equipped with beds and kitchens, and used for pleasure cruising. You can live aboard **cabin cruisers**, too, which travel on open water as well as canals.

A FLYING SUCCESS Guido Cappellini's F1 Powerboat flies across the surface of Doha Bay during the Qatar F1 Powerboat Grand Prix in 2009. This racing catamaran is tearing along at over 125 mph (200 km/h) around a course marked by floating buoys. As many as 24 F1 powerboats take part in each race, battling for position, because points earned count toward the coveted World Championship title.

F1 Powerboats are the ultimate speed machines on water. Equipped with monstrous 425 horsepower engines, they weigh around 1,102 lb (500 kg) and can accelerate from a standing start to 100 mph (160 km/h) in only four seconds, quickly hitting top speeds of around 140 mph (225 km/h). Inside its sleek carbon fiber body, the driver is firmly strapped in, and protected by a crash cabin, as he pushes his powerboat to the limit. There are no gears and no brakes. It is edge-of-your-seat racing, with boats taking tight corners at 62–93 mph (100–150 km/h). Cappellini won this and four other races in the 2009 season, earning him the world-championship crown for a record tenth time.


AIR

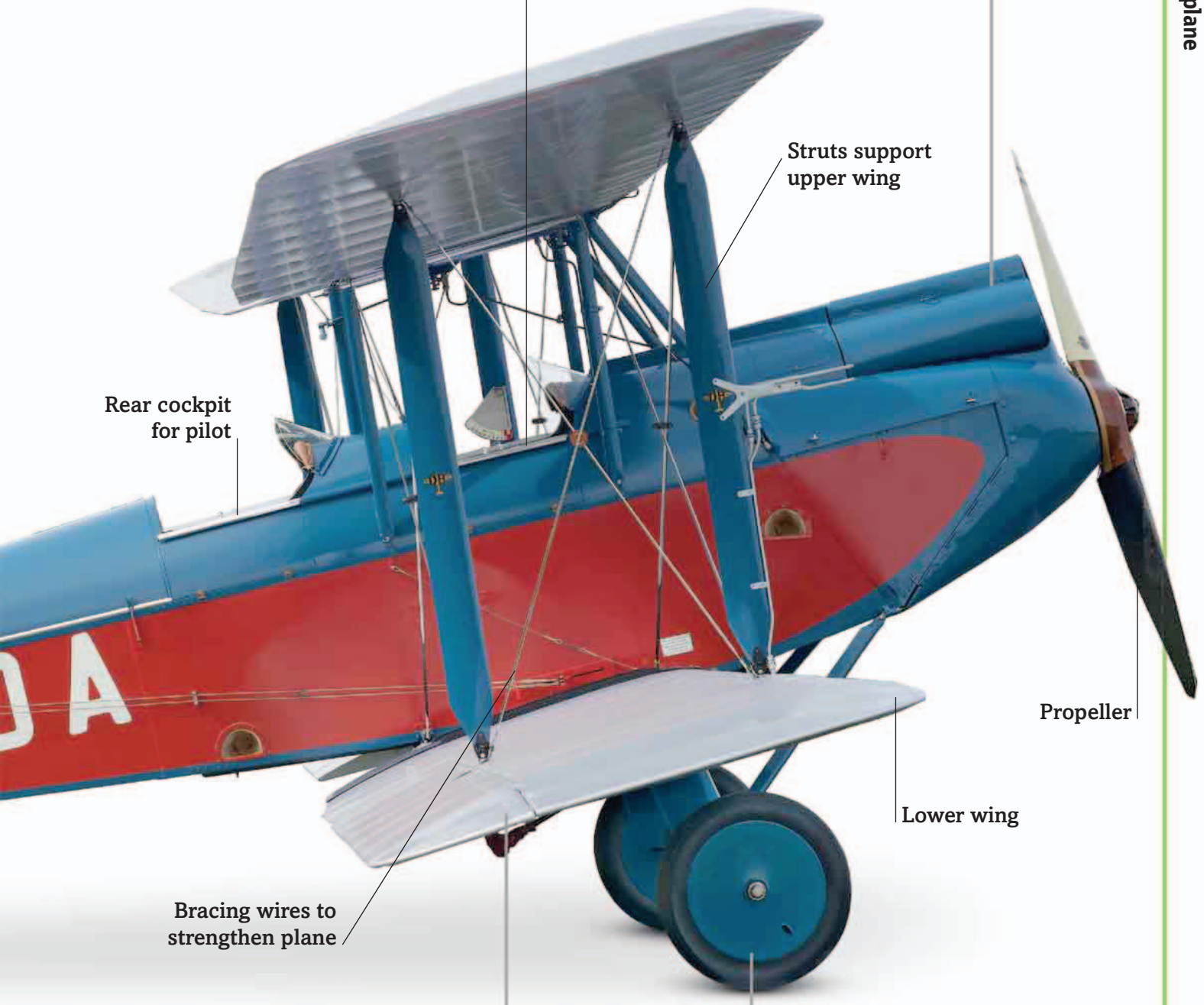
Airplane

Airplanes are heavier than air, so they need to overcome the force of gravity, which pulls them toward the ground. They do this with the help of curved wings, which produce an upward force, called lift, as the plane moves through the air. Most aircraft today are monoplanes, which means they have a single set of wings. This **de Havilland DH60 Gipsy Moth** is a biplane, with two pairs of wings and an open cockpit with two seats.

Tail › Most aircraft have a tail consisting of a fixed fin, horizontal tailplanes, and hinged rudder and elevator flaps. The rudder is moved by controls in the cockpit to help the aircraft turn. Elevators control up and down movements.

Fuselage › This is the body of the aircraft to which wings are attached, and where the pilot and passengers sit. The Gipsy Moth's fuselage is made of a wooden frame covered in fabric. Most plane fuselages today are made of metals or materials, such as carbon fiber.

Engine › Powered aircraft have an engine that generates thrust to propel them forward. Modern airliners and military planes use jet engines, while many light aircraft, such as the Gipsy Moth, use an engine that turns a propeller to move them through the air.



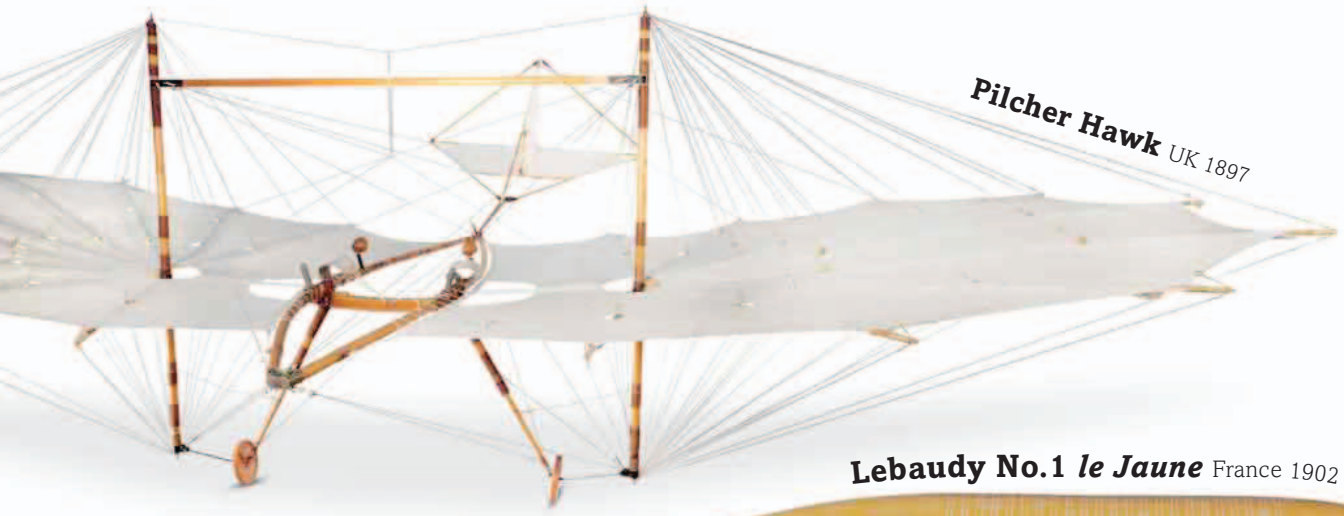
Aileron › This hinged flap at the rear of the wing can be raised or lowered, together with the aileron on the other wing, to tilt the aircraft. When used together with the rudder, the ailerons allow the pilot to perform sweeping, angled turns.

Undercarriage › Also known as landing gear, these are the parts of the aircraft used for moving on the ground and for takeoff and landing. On most aircraft these are sets of wheels, but some aircraft have skids or floats so they can operate on water.

Taking to the skies

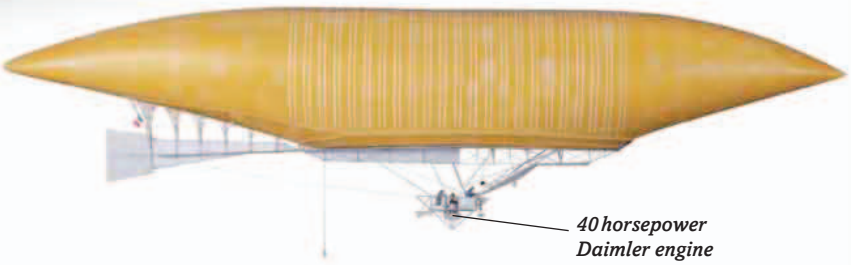
For thousands of years, people have dreamed of flying. However, getting off the ground successfully proved impossible until the invention of lighter-than-air craft, such as balloons and airships, and research into the principles of flight using gliders.

In 1783, following a test flight carrying a sheep, a duck, and a rooster, the **Montgolfier Hot-air Balloon** took off in Paris, France, with two human passengers. Paris was the center of the new balloon age. Just 10 days later the city saw the launch of the first hydrogen-filled balloon, the



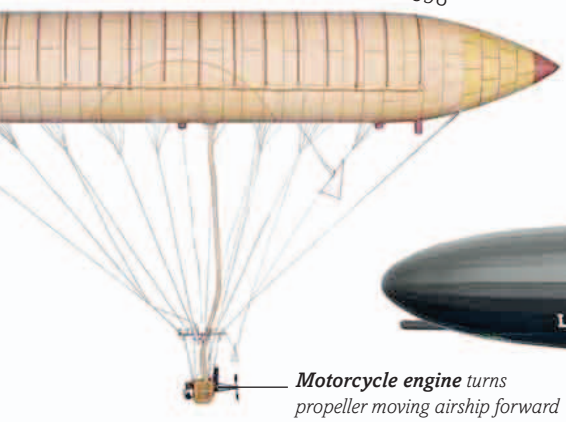
Pilcher Hawk UK 1897

Lebaudy No.1 *le Jaune* France 1902



40 horsepower Daimler engine *turns two propellers*

Santos-Dumont No.1
Brazil/France 1898



Motorcycle engine *turns propeller moving airship forward*

Zeppelin LZ 96 Germany 1917

Hinged rudder *helps steer the craft*

Gondola *holds crew and up to 20 passengers*

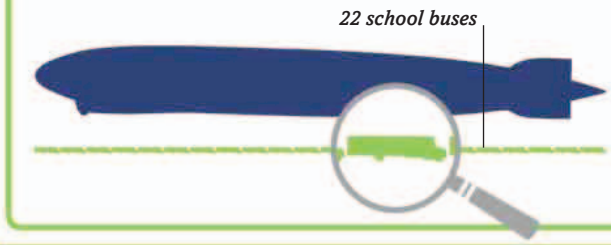
LZ 127 *Graf Zeppelin* Germany 1928

778-ft- (237-m-) long hull *covered in cotton over a rigid frame of aluminum alloy girders*

17-ft-4-in- (5.3-m-) long glider

Passengers on the *Graf Zeppelin* had their own beds, a main dining room, and meals made onboard.

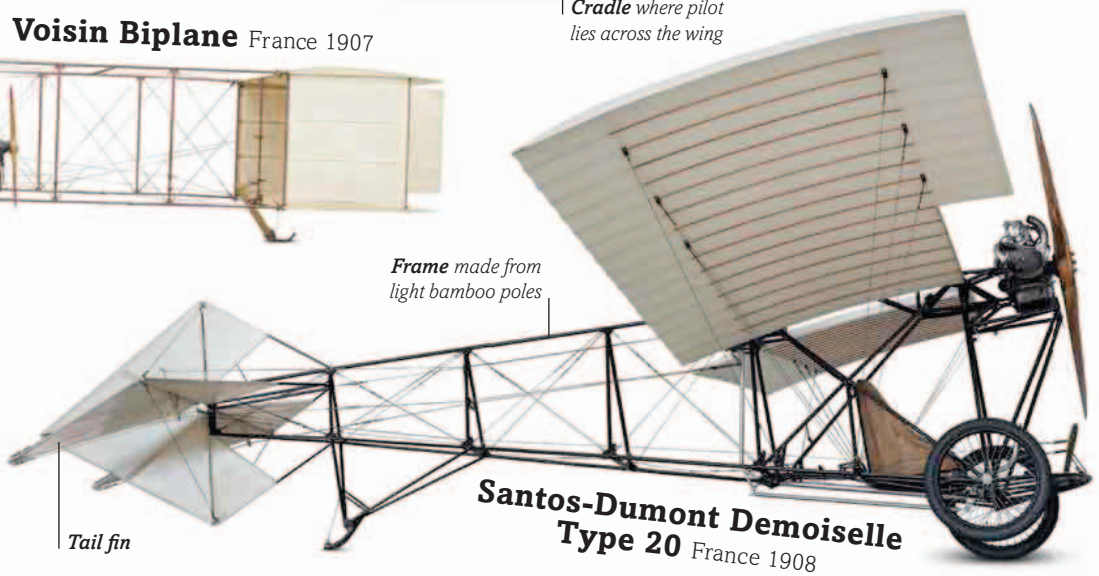
LZ 127 *GRAF ZEPPELIN*



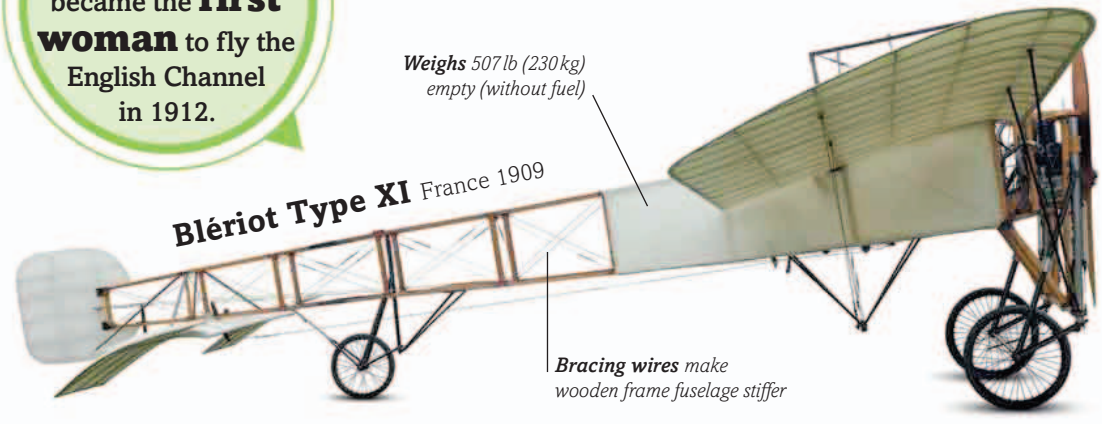
22 school buses

la Charlière, and, in 1898, the first flight of the airship **Santos-Dumont No.1**. In Germany, large airships, such as the **Zeppelin LZ 96**, scouted and bombed during World War I, while postwar airships, such as the ***Graf Zeppelin***, offered long-distance transportation to the wealthy. Other inventors believed that winged gliders were the way up. In the 1890s, German engineer Otto Lilienthal made many successful flights in gliders such as the ***Normal Apparatus***. His work inspired other glider designs, as well as the Wright Brothers' work on a powered aircraft.

First planes



Harriet Quimby, in a Blériot XI, became the **first woman** to fly the English Channel in 1912.



On December 17, 1903, bicycle-maker Orville Wright lifted off into the air in a powered aircraft. This first flight lasted only 12 seconds and covered less than the length of a modern airliner, but it marked the beginning of a new age.

Built by two brothers, the ***Wright Flyer*** was a biplane, with two sets of wings, and two propellers spinning behind them. The **Voisin Biplane** and **Shorts S27** copied this pusher-propeller design, but other aircraft, such as the **Santos-Dumont Demoiselle**, mounted their

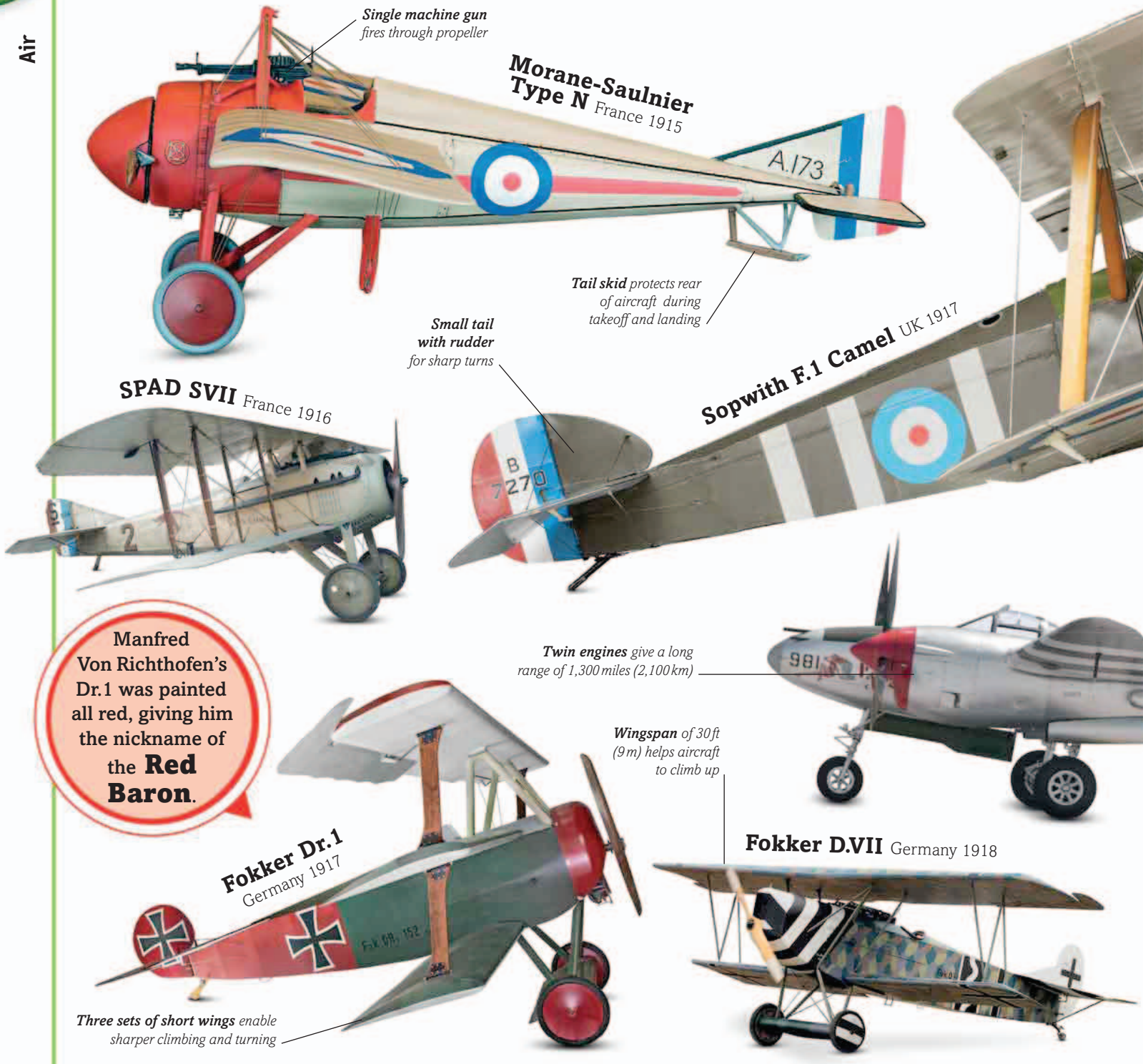
The wires on the Fokker gave it the name ***Spin***—Dutch for **spider**.

engine and propeller at the front, or were monoplanes, with a single pair of wings. Early aircraft were built light, using wood, cloth-covered wings, and wires to brace and stiffen their structures. The **Blériot XI** carried French aviator Louis Blériot on the successful first flight from France to England across the English Channel in 1909. The **Deperdussin Type A** flew 60 miles (100 km) at a record speed of 60 mph (100 km/h) in 1911, carrying two people. This, and other record breakers, helped to prove that planes could be a practical form of transportation.

THE GIRL OF NERVE Daredevil wingwalker Lilian Boyer hangs from the wingtip of a Curtiss JN-4 Jenny biplane without a safety harness. Flying was new to the public in the 1920s and a ride in a biplane could be an unnerving experience for some, even when safely strapped into their seat. So, large crowds were thrilled by the exploits of barnstormers who performed amazing feats of daring in the sky.

In 1921, Boyer, a 20-year-old restaurant waitress, proved fearless when on her second flight in an aircraft, she stepped out of her seat and onto the wing. Later that year, she teamed up with former World War I pilot Billy Brock. The pair performed 352 shows across North America throughout the 1920s, dazzling crowds with their exploits. Boyer would stand on the wing of the aircraft as it performed a loop-the-loop, or dangle from the wing hanging by one hand, or even by a cord she gripped with her teeth! She also mastered jumping from a speeding car to a plane—a stunt she pulled on 143 occasions before bans on low flying came into place in 1929. Miraculously, Boyer lived to the grand age of 88.

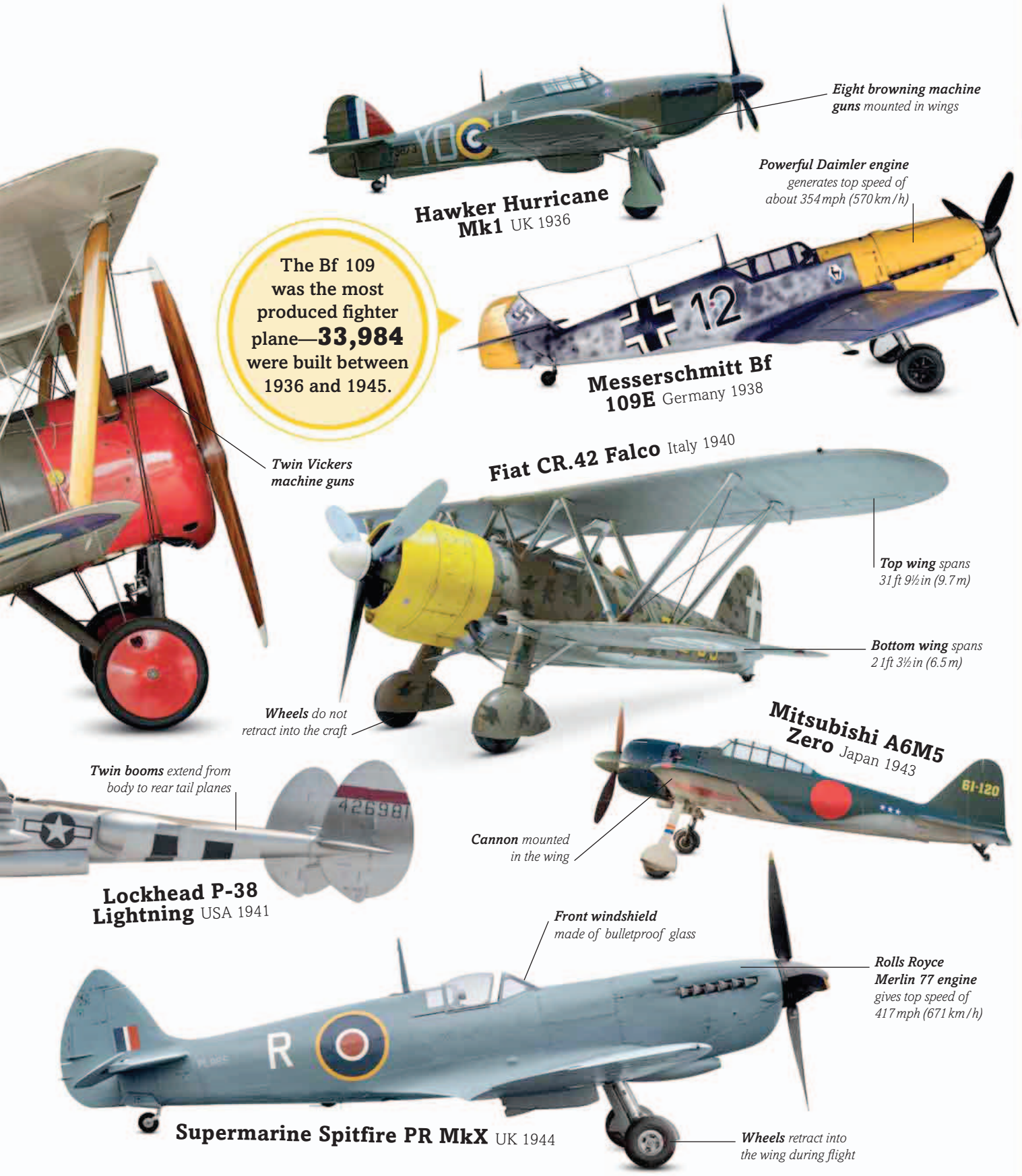
Fighter planes



Manfred Von Richthofen's Dr.1 was painted all red, giving him the nickname of the **Red Baron**.

Fast and maneuverable, fighter planes were an air force's hunter-killers during World Wars I and II. Their forward-firing weapons, such as cannons and machine guns, were mounted on the nose or the wings to shoot down other aircraft.

Early World War I fighters, such as the **Morane-Saulnier Type N**, preyed on slow, often unarmed, bombers and reconnaissance aircraft. They were soon outpaced by faster fliers, such as the **Sopwith Camel** and **Fokker D.VII**, which engaged in furious dogfights against each other.



The famous German fighter ace, Baron Manfred von Richthofen, made 19 of his 80 "kills" in his **Fokker Dr.1** triplane. Fighter designs mostly moved from biplanes (with two pairs of wings) to monoplanes (with a single pair of wings) after World War I, and aircraft such as the **Hawker Hurricane Mk1** and the **Messerschmitt Bf 109E** battled in the sky. Some fighters, such as the **Mitsubishi A6M5 Zero**, also served as bombers, while the **Supermarine Spitfire PR MkX** relied on its speed to avoid other fighters as it took photos over enemy lines.

Strike force

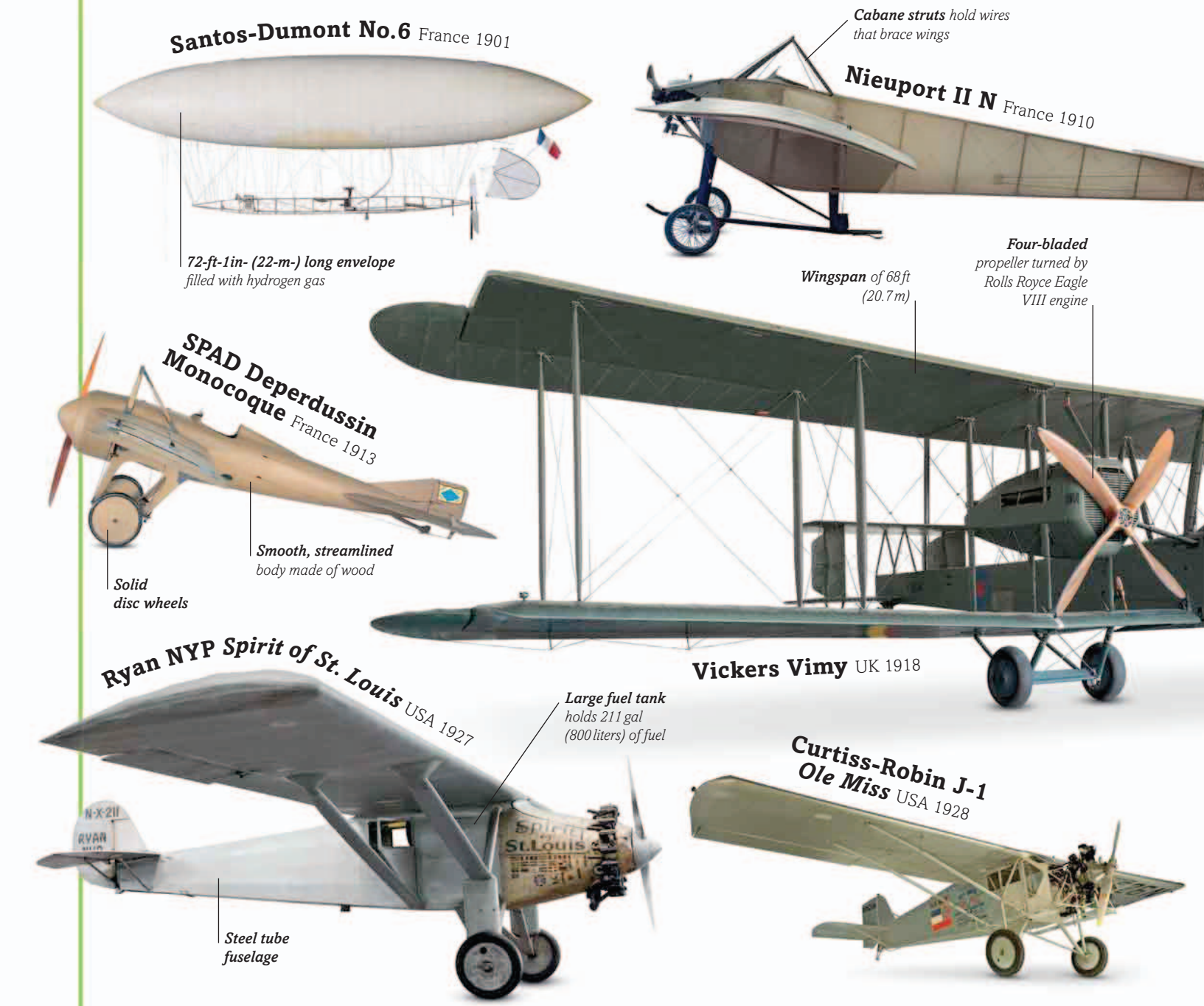
The B-2 *Spirit* is the world's most expensive aircraft, costing **$2.1 billion** each!

Strike aircraft attack ground targets using bombs or missiles. The first bombers were regular planes from which small bombs were dropped by hand. Special bombers were developed at the end of World War I and saw major action in World War II.

Some World War II bombers, such as the **Junkers Ju87 *Stuka***, would dive low to bomb enemy forces on the ground. Others operated from high altitude, as much as 29,528 ft (9,000 m) in the case of the **Boeing B-17G Flying Fortress**. The **Avro Lancaster** had over double the bomb-carrying

capacity of the B-17G and more than 7,000 were built. Both were heavily armed, with machine gunners in turrets. Made out of wood, the **de Havilland DH98 *Mosquito*** relied on its speed and agility to evade enemies. Fifty years later, the **Northrop Grumman B-2 *Spirit*** uses stealth technology to strike its targets undetected. Some jet-powered bombers could travel long distances, such as the **Tupolev Tu-22M3**, with a range of 4,200 miles (6,800 km), and the eight-engine **Boeing B-52H Stratofortress**, which could fly more than 10,000 miles (16,000 km).

Racers and record-breakers

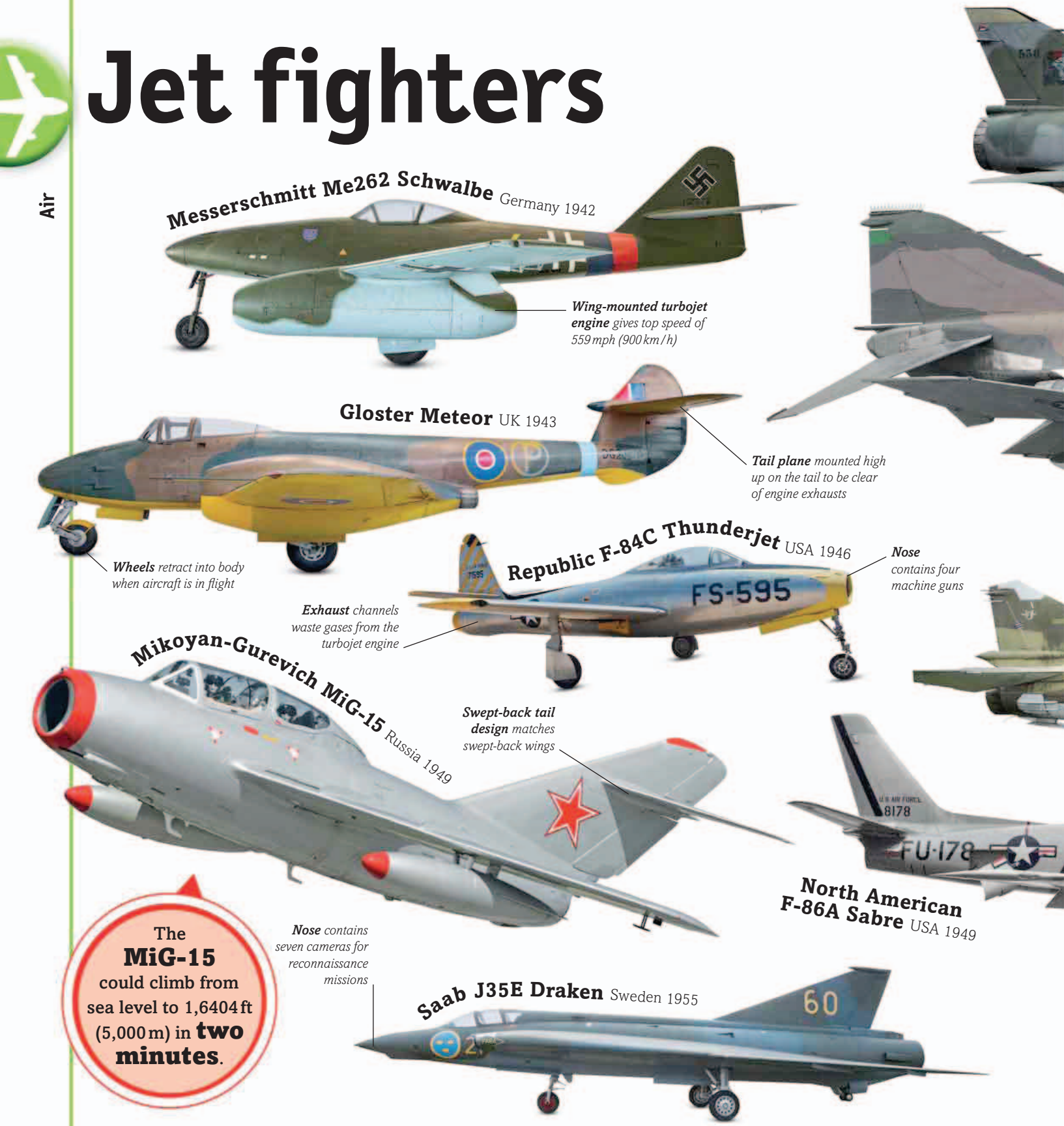


Getting into the air wasn't enough for some pilots and engineers. They wanted to push their planes to the limit and fly higher, faster, longer than others. Races were held, records set and broken, as aircraft became stronger, more powerful, and reliable.

In 1901, the **Santos-Dumont No.6** airship won one of the first aviation prizes—100,000 French francs in 1901 for a flight around the Eiffel Tower. In 1919, the **Vickers Vimy** made the first nonstop flight across the Atlantic. American aviator Charles Lindbergh completed a 33½ hour

nonstop solo flight from New York to Paris in 1927 in the ***Spirit of St. Louis***. In 1935, a **Curtiss-Robin J-1** called *Ole Miss*, aided by inflight refuelling, stayed aloft for 27 days. As aircraft design developed, speed records were frequently broken. The **SPAD Deperdussin Monocoque** set a record of 130 mph (210 km/h), while the **Supermarine S6B** and the **Macchi Castoldi M.C.72** broke the 373 mph (600 km/h) and the 435 mph (700 km/h) barriers. Even faster was the rocket-powered **Messerschmitt Me163 Komet**, which reached 624 mph (1,005 km/h) in 1941.

Jet fighters



The **MiG-15** could climb from sea level to 1,6404 ft (5,000 m) in **two minutes**.

Developed during World War II, jet fighters are mostly fast, nimble single-seaters that carry a wide range of weaponry, from cannons to missiles. They attack and chase off enemy fighters to establish air superiority over a region.

North American F-86A Sabres and **Mikoyan-Gurevich MiG-15s** fought each other during the Korean War of 1950. The **Republic F-84C Thunderjet** flew 86,408 missions during the same war, and was the first mass-production jet fighter that could refuel

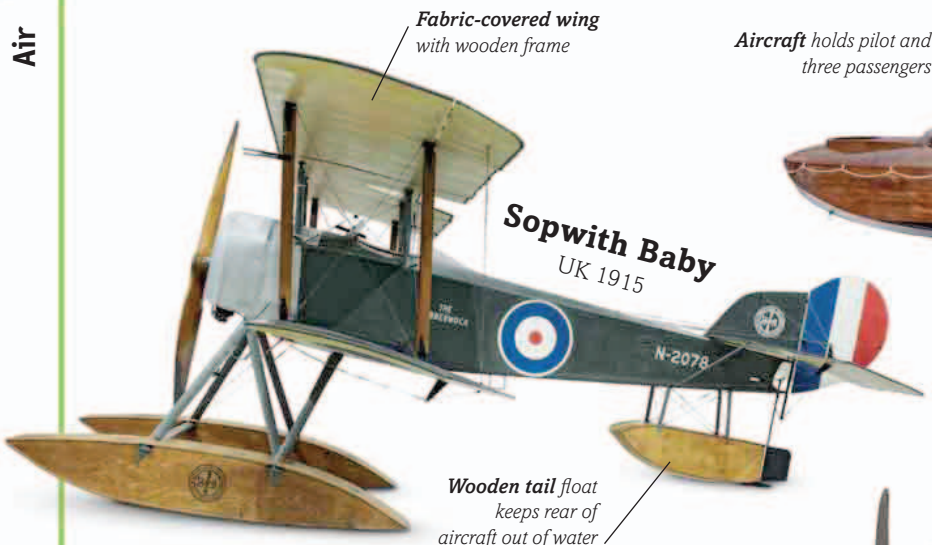
More F-4 Phantoms were built than any other US supersonic jet—**5,195** in total.

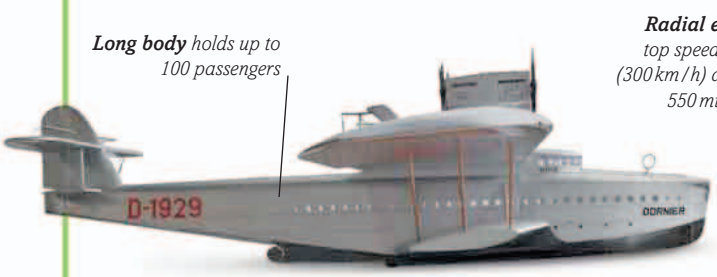
midair from a tanker aircraft. The **Mikoyan-Gurevich MiG-23** and the **Dassault Mirage III** could operate as fighter-bombers, carrying ground attack weapons under their bodies and wings. Designed for quick operations, the **Saab J35E Draken**, could be re-armed in just 10 minutes. It could take off from roads as well as runways. Modern warbirds, such as the **Lockheed Martin F-22 Raptor** and the **Eurofighter Typhoon FGR4**, are versatile. They can attack air and ground targets, as well as perform reconnaissance missions.

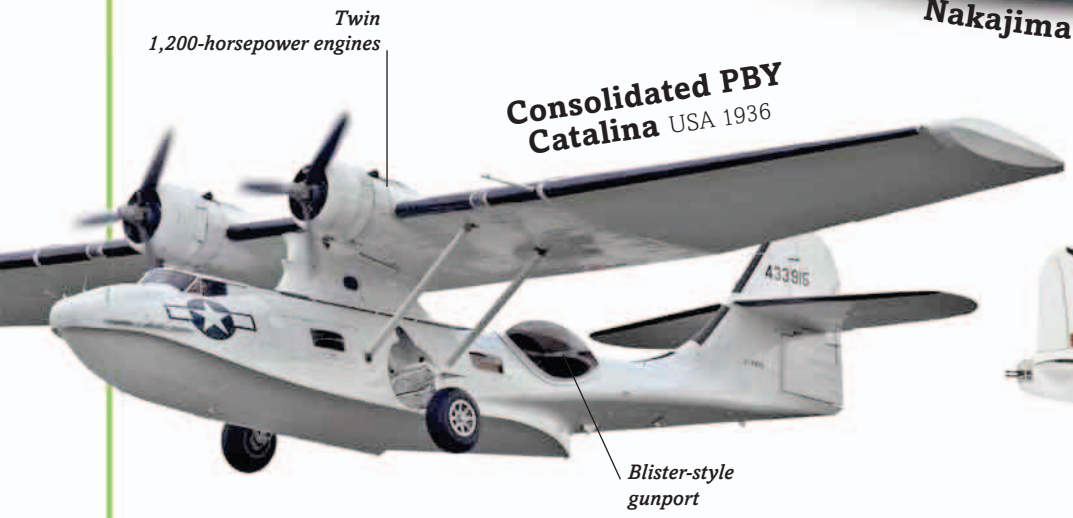
SUPER SPEED An extraordinary sight greets the eyes as a United States Navy Grumman F-14 Tomcat accelerates just 500 ft (150 m) above the Pacific Ocean. A cloud of condensed water vapor forms around the aircraft, known as a shock collar, or vapor cone. The aircraft will shortly go supersonic and travel faster than the speed of sound, an event often accompanied by a loud noise, known as a sonic boom.

When a fast aircraft travels, it generates a series of pressure waves in the air. These waves travel at the speed of sound, approximately 761 mph (1,225 km/h) at sea level, and a little lower at higher altitudes. As the aircraft's speed increases, the waves are forced together to form a single shock wave, which makes a thunder-like boom when released. Most sonic booms last between 0.1 and 0.5 seconds. The first supersonic flight was in 1947. Today, many military jet aircraft regularly travel at supersonic speeds. The F-14 has a top speed of more than 1,500 mph (2,400 km/h) at high altitude. Only two passenger airliners have ever operated at supersonic speeds: the Russian Tupolev Tu-144 and the British/French Concorde.

Seaplanes







Planes that can land and take off from water are known as seaplanes. There are two types of these versatile machines—floatplanes, which sit on water using pontoons (buoyant floats), and flying boats with a watertight body, like a boat.

Floatplanes saw service in both the World Wars. The **Sopwith Baby** patrolled coasts and spotted airships in WWI. The **Nakajima Type 95 Willow** flew as a light bomber during WWII, while military flying boats, such as the **Short Sunderland** and **Consolidated PBY Catalina**,

Wings *with 46ft (14m) span could fold back for storage on a ship*

Supermarine Walrus *UK 1939*

Front deck *where crew stand to moor aircraft*

Tail rudder

Wheels *retract into body while flying or cruising on water*

Cabin *holds 10 passengers*

de Havilland DHC-3 Otter Canada 1953

Wingspan *of 57ft 8in (17.6m) enables aircraft to take off over short distances*

Turboprop engine *gives top speed of 330mph (530km/h)*

Nose cone *contains radar system*

Beriev Be-12 *Chaika*
Russia 1960

This plane can scoop **1,320 gallons** (5,000 liters) of water from a lake in **10 seconds**.

Pusher propeller *forces air back to move aircraft forward*

Lake LA-4
USA 1967

Retractable *tricycle undercarriage*

Wing

Large float *underneath wing*

Canadair CL-215
Canada 1967

performed patrols, hunted submarines, and escorted ships. Other flying boats, such as the 12-engined **Dornier Do-X**, carried passengers across long distances. Some seaplanes are amphibious and can operate from land or water. The **Supermarine Walrus** would take off from a warship and land on water, and was then returned to the ship by crane. It was used in Canada along with other seaplanes, such as the **de Havilland Otter** and the **Canadair CL-215**. The Canadair is designed to skim a lake or river scooping up large quantities of water to drop on forest fires.

Light aircraft

Boeing-Stearman PT-17/N2S Kaydet USA 1940

Wings *made of wood and covered in fabric*

Wing *carries 38.8 gal (147 liters) of fuel*

Cessna 172 USA 1964

Beagle Pup Series 2 UK 1969

Two-blade metal propeller *driven by 150 horsepower engine*

Cabin *holds eight passengers and has single door*

Cessna 421B USA 1973

Wings *have a span of 20 ft (6.1 m)*

Pitts Special S-2A USA 1973

Ailerons *on upper and lower wings help plane perform complete 360° roll in two seconds*

A **S-2A** set a world record in 2014, performing **81 spins** in a row.

Light aircraft are small civilian craft with one or two engines and a fully loaded weight of less than 12,500 lb (5,670 kg). They are used for travel, learning to fly, aerobatics, and racing, and some as airmail carriers, ambulances, or cropdusters.

Some light aircraft are very light, such as the **Bede BD-5J**, which weighs 358½ lb (162.7 kg) empty, making it the lightest jet aircraft in the world, and the **Flight Design CTSW**, which weighs 702 lb (318.4 kg) empty and has a parachute system that can carry the entire

In 2014, Matt Guthmiller, age **19**, became the **youngest** to fly around the world in an A36.

aircraft to the ground in an emergency. The **Beagle Pup Series 2** was used for touring and aerobatics, while the two-seater **Pitts Special S-2A**, which can spin, roll, and climb sharply, is just used for tricks. Early Pitts planes were offered as kits to be built at home, as was the all-aluminum **Vans RV-6**. In contrast, the **Beechcraft A36 Bonanza** is one of more than 17,000 Bonanzas built in factories. The most manufactured light aircraft of all is the four-seater **Cessna 172**, of which more than 43,000 were produced.

Plane spotting

Early passenger planes were converted bombers and other military aircraft. Planes specially built for air travel truly arrived in the 1920s and 1930s. Today, flying has become a fast, convenient, and common form of transportation.

The **Fokker F.II** carried just four passengers, while the **Ford 5-AT Trimotor** could hold 13, plus two crew members. The **Douglas DC-2** could carry one passenger more and was flown by more than 30 airlines all around the world, as was the simple but rugged **de Havilland DH89**

Tupolev Tu-154 Russia 1969

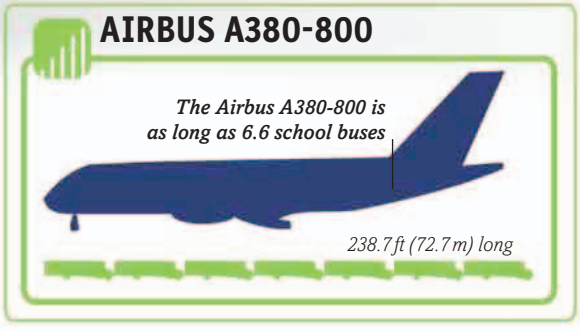
Dornier Do228-101 Germany 1985

Airbus A320-214 Multinational 1995

Today, 25,000 passenger planes carry more than **3.4 billion passengers** every year.

Airbus A380-800 Multinational 2005

Boeing 787-8 Dreamliner USA 2009



Dragon Rapide. Larger airliners powered by jet engines emerged after World War II. The first short-haul jet airliner, the **Sud-Aviation Caravelle**, carried 80 passengers, while the **Tupolev Tu-154** could carry up to 180. Today, the biggest of all is the **Airbus A380-800**, which can carry up to 853 people on two passenger decks. Some modern airliners can travel long distances without landing to refuel. The **Boeing 787-8 Dreamliner** can fly up to 8,000 miles (13,000 km) nonstop—enough to make it from the USA to China.

COMING IN LOW Vacationers sunning themselves on the Caribbean island of Saint Martin get their cameras out as an Air Caraibes Airbus A330 airliner comes in to land at Princess Juliana International Airport. The stunning sight is repeated over the sands of Maho Beach several times day, as the Caribbean island airport receives more than 58,000 aircraft movements (takeoffs or landings) every year.

The airport's 7,545 ft- (2,300 m-) long runway is relatively short by modern standards, and it stretches close to the airport's boundary with the beach. An Airbus A330, which can carry more than 200 passengers, needs at least 3,280 ft (1,000 m)—preferably more—to come to a halt once it has touched down. As a result, pilots make their approach over the shimmering waters of the Caribbean as low as they can, in order to get their plane's wheels on the tarmac as quickly as possible. Planes can be just 65 to 100 ft (20 to 30 m) above the ground by the time they fly over the beach. Maho may not be the best beach on the island, but it draws large crowds of plane-spotters, eager to get close to big airliners in flight.

Straight up and supersonic

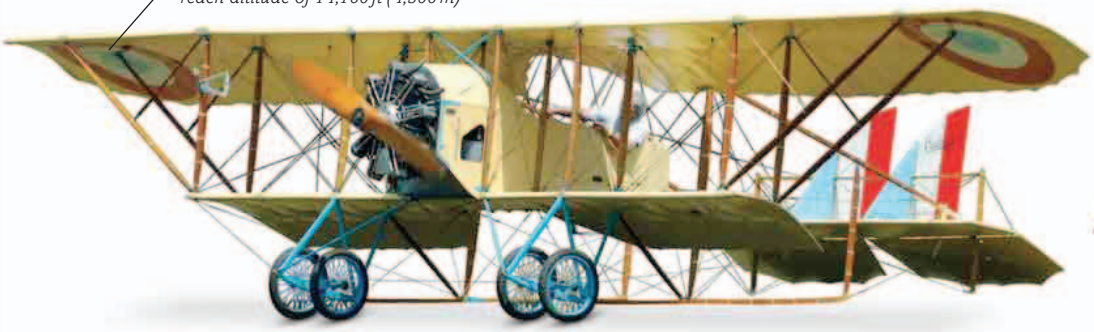
The Bell X-1 was nicknamed ***Glamorous Glennis*** after the pilot's wife.

The quest for speed led to supersonic aircraft—planes able to fly faster than the speed of sound, 767 mph (1,235 km/h) at sea level. Engineers have also created aircraft that can take off and land vertically, like a helicopter—VTOL planes.

The first supersonic aircraft was the rocket-powered **Bell X-1** piloted by American Charles "Chuck" Yeager. Improvements in jet engines saw startling increases in speeds. The **Fairey Delta 2** was the first to fly faster than 1,000 mph (1,609 km/h), the **Lockheed F-104G Starfighter**

the first to reach 1,242 mph (2,000 km/h), and the **MiG-21** topped 1,479 mph (2,380 km/h). Then, in 1976, the **Lockheed SR71 Blackbird**, a jet spy plane, set a record of 2,193 mph (3,529 km/h), which has not been broken since. VTOL aircraft are used in places without long runways. Some, such as the **Hawker Siddeley Harrier GR 3** and **Yakovlev Yak-38**, have engine nozzles that move to direct thrust downward or behind. Tilt-rotor planes, such as the **Bell XV-15**, swivel their entire propeller-spinning engines upward for takeoff and forward for regular flight.

Eyes in the sky

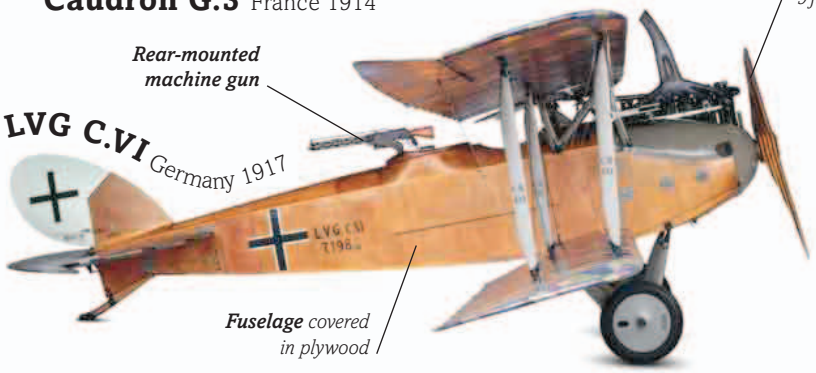


44ft (13.4m) upper wing *helps plane reach altitude of 14,100ft (4,300m)*

Caudron G.3 France 1914

Large, greenhouse-style canopy *for good visibility*

The G.3 was an **easy target** for WWI fighters due to its **slow** speed of 66mph (106km/h).



Rear-mounted machine gun

LVG C.VI Germany 1917

Fuselage *covered in plywood*

Wooden propeller *9ft (2.8m) in diameter*

North American O-47B USA 1938

Pilot *wears space suit in the cockpit for flying at high altitudes of 70,000ft (21,000m) above sea level*

Wingspan *of 46ft 5in (14m)*

Piper L-4H Grasshopper USA 1944

Rear seat, *where an observer could face forward or backward, with table for maps and radio*

Radar *detects approaching aircraft*

Lockheed U-2 USA 1955

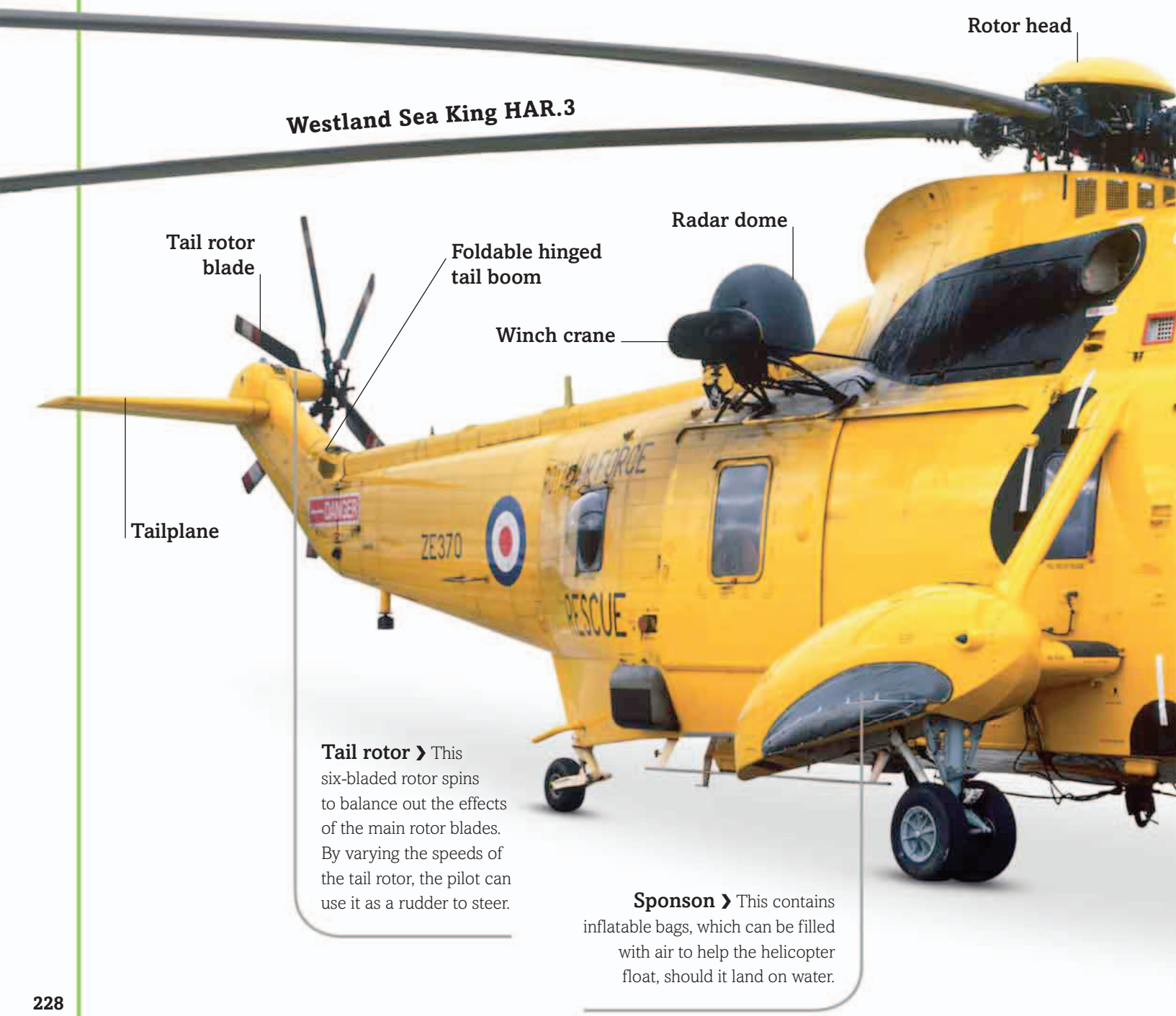
Reconnaissance planes scout the land and sea from above. Some go further, acting as spies in the sky using telephoto lenses and other tools to spot troop positions and detect enemy weapons, facilities, or other crucial activity on the ground.

The first spotter planes, such as the **Caudron G.3** and the **LVG C.VI**, were used to detect enemy artillery and troop movements. Later observation aircraft, such as the **OV-10 Bronco**, could scout territory and carry weapons. It could also take off from roads or makeshift runways,

and fly more than 1,400 miles (2,200 km). The **SR-71 Blackbird** was a dedicated spy plane that operated at high speed and altitude, out of the range of enemy ground-to-air missiles. No Blackbird was ever shot down by enemy forces. Advanced fighters feature stealth technology that confuses enemy radars and other sensors, in order to spy undetected. Unmanned aerial vehicles (UAVs), or drones, such as the **BAE Systems Mantis**, can fly long missions gathering information without risking pilots' lives. The Mantis can fly up to 30 hours.

Helicopter

A helicopter's long, thin rotor blades have a curved shape, similar to that of an aircraft's wing. When these blades are spun quickly by the engine, they travel through the air and, like an aircraft wing, create lift. Their ability to take off and land vertically, and to hover midair, make helicopters incredibly useful for military and police work, and search-and-rescue missions, as performed by this **Sea King**.



Tail rotor › This six-bladed rotor spins to balance out the effects of the main rotor blades. By varying the speeds of the tail rotor, the pilot can use it as a rudder to steer.

Sponson › This contains inflatable bags, which can be filled with air to help the helicopter float, should it land on water.

Turbine engine › The helicopter's two Rolls Royce Gnome turboshaft engines spin the rotor head, which can be angled to change the helicopter's direction. The Sea King has a cruising speed of 129 mph (208 km/h), and a maximum range of 764 miles (1,230 km).

Rotor blade › The rotor blades are fitted to the rotor head, which is spun by the engine to generate lift. The Sea King can rise up at speeds of 33 ft (10 m) per second. When the helicopter is stored on a ship, or in a hangar, the blades can be folded up.

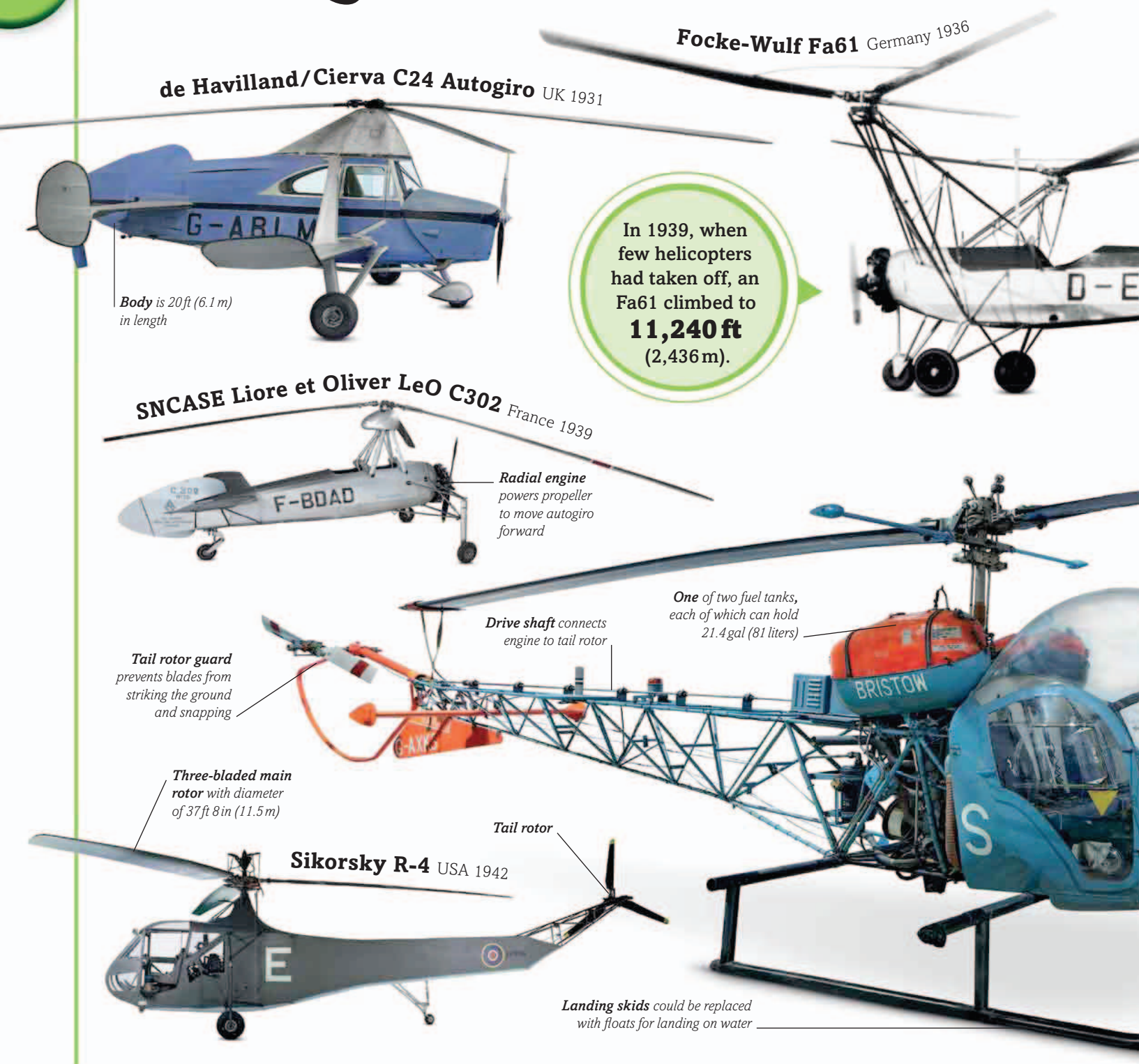
Interior › The pilot and the copilot fly the helicopter from the cockpit, while two crew members operate the radio and winch system, which can lift people out of the water and into the helicopter. The Sea King can hold up to 18 rescued people or 6 stretchers.

Powerful forward-facing headlight

Hull and avionics › The Sea King's hull-shaped body enables it to float on water. Stored inside its nose are radio and navigation electronics that enable the helicopter to find stricken boats and people at sea.

Undercarriage wheels

Whirlybirds



With long, thin, wing-shaped blades whizzing around, it is no surprise that the first autogiros and helicopters got the nickname *whirlybirds*. These versatile craft first came into their own in the 1930s and 1940s.

Autogiros, such as the **Cierva C24**, use a main rotor for lift, but also have a propeller at the front to provide thrust. This gave the C24 a top speed of 110mph (177km/h). The experimental **Focke-Wulf Fa61** came with two sets of rotors, to increase lift, but only two were ever made.

A Bell 47D was the **first helicopter** to fly over the **Alps** in 1950.

In contrast, more than 5,600 Bell 47 helicopters were built between 1946 and 1974. These included the **Bell 47G**, which became famous for medical evacuation, a task also performed by the **Westland Dragonfly HR3,** which flew the world's first scheduled helicopter service from 1950 onward. The **Sikorsky R-4** was the first helicopter used by the American and the British militaries, rescuing injured air crash survivors in Asia as early as 1944. The Soviet Union's first production helicopter was the **Mil Mi-1M**, of which more than 2,500 were eventually built.

Working choppers

The ability to hover in midair makes helicopters ideal platforms for aerial photography, search and rescue, and reconnaissance missions. They can also operate from isolated areas and city helipads, ferrying people and supplies.

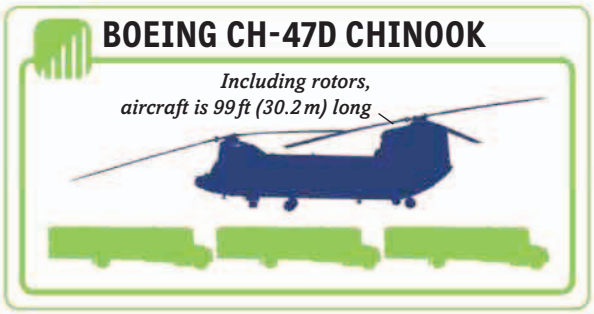
The 1960s saw the production of both tiny autogiros and giant helicopters. The single-seater **Wallis WA-116** was just 11 ft 2 in (3.4 m) long, but could fly more than 125 miles (200 km), while the **Mil Mi-8** was 60 ft (18.2 m) long and could carry 27 people or 6,614 lb (3,000 kg) of cargo. Biggest

of all is the 131-ft- (40-m-) long Mil Mi-26. The **DragonFly 333** was developed for filmmakers and archaeologists to perform aerial surveys, while the **Robinson R22 Beta** was used to patrol pipelines and to get around large farms or ranches. The **MD900 Explorer** is used by coastguards and the police forces, and also serves as an air ambulance, a task some **Bell 407** seven-seater helicopters also perform. Other 407s transport workers to and from offshore oil rigs, while variants of the **Schweizer 269C** have been used to train more than 60,000 army helicopter pilots.

Air support

Military helicopters serve armies, navies, and air forces all over the world. Their ability to land in small spaces, hover in midair, and drop supplies accurately make them invaluable on the battlefield, as well as behind the lines.

Many military helicopters, such as the **Sikorsky S-70i *Black Hawk***, are multi-purpose, able to move troops and equipment, or scout land or sea for threats. Some, such as the **Bell AH-1 Cobra** and the **Kamov Ka-52 *Alligator***, are designed to attack mostly ground targets, using weapons such



Westland Sea King HC4 UK 1979

Boeing CH-47D Chinook USA 1982

Wide rear cargo ramp allows large items to be loaded

Kamov Ka-52 *Alligator* Russia 1996

Bottom set of rotor blades spins in the opposite direction to the top set

Rotorless tail

Armored body can withstand hits from gunfire

More than **2,100** versions of the *Black Hawk* have been built since its first production in 1976.

Eurocopter UH-72 Lakota France 2004

Set of three tailfins

Cabin seats up to 18 passengers

Landing skids

Four-bladed tail rotor helps in flight stability

Cockpit doors can be ejected in an emergency

Landing gear absorbs shocks

Sikorsky S-70i *Black Hawk* Poland 2011

as cannons, rockets, or small guided missiles. Larger choppers can deploy troops, supplies, or equipment, or evacuate the wounded or civilians out of a warzone. The **Westland Sea King HC4** can carry up to 28 commandos in its cabin, while the **Boeing CH-47D Chinook** can seat nearly 55 troops, or carry 26,455.5 lb (12,000 kg) of cargo. The **Kamov Ka-25PL**, with two sets of rotors, one above the other, is designed to hunt and attack enemy submarines. The same role is performed by the **Mil Mi-14 BT**, which can carry one torpedo or eight depth charges.

Spacecraft

Spacecraft are machines that are launched by rocket engines out into space. Many of them are unmanned probes, sent out to explore parts of the solar system. A small number have been manned, and have carried more than 500 people into space. In 1969, an American **Apollo 11 spacecraft** was launched by a Saturn V rocket and carried three astronauts into orbit around the moon. Two of them descended in the Lunar Module onto the moon's surface.

Apollo 11 spacecraft

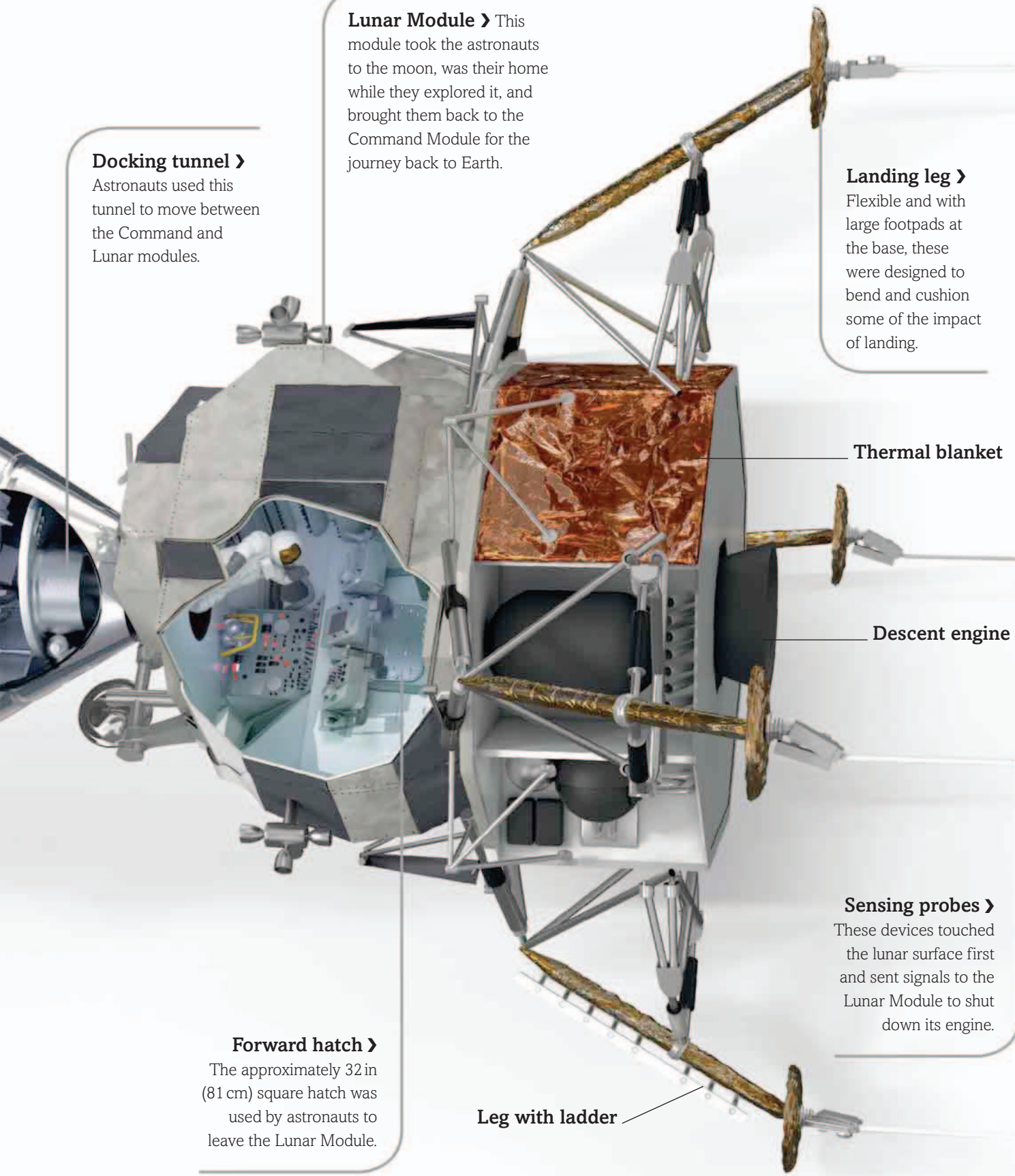
Engine nozzle

Service Module › This module provided life-support systems and power for the crew, and housed the spacecraft's main engine.

Fuel tanks › Tanks within the Service Module supplied fuel to the main engine.

Thrusters › Small thrusters made fine adjustments to the spacecraft's movements.

Command Module › The 10-ft-6-in- (3.2-m-) tall Command Module was the only part of the Apollo spacecraft to return to Earth. It orbited the Moon, while the astronauts completed a return journey to its surface in the Lunar Module, then separated from the Service Module and traveled back to Earth.



Lunar Module › This module took the astronauts to the moon, was their home while they explored it, and brought them back to the Command Module for the journey back to Earth.

Docking tunnel › Astronauts used this tunnel to move between the Command and Lunar modules.

Landing leg › Flexible and with large footpads at the base, these were designed to bend and cushion some of the impact of landing.

Thermal blanket

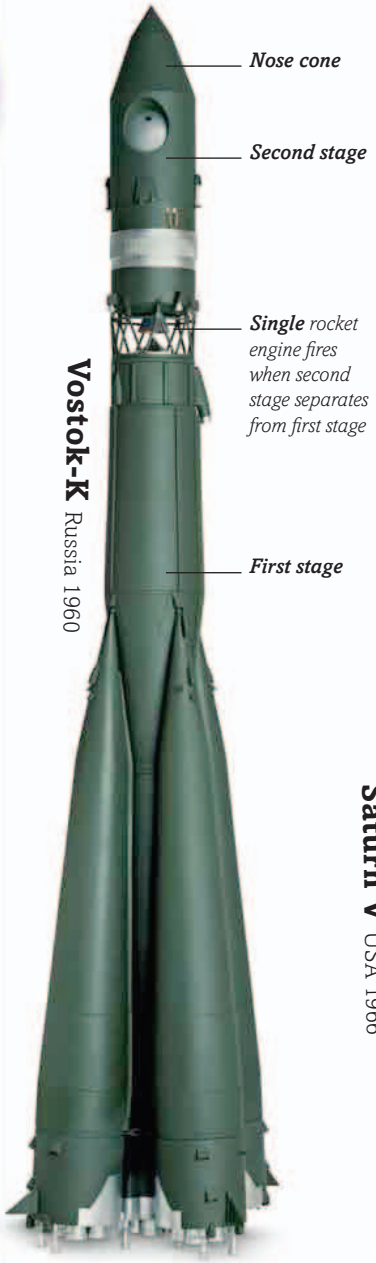
Descent engine

Sensing probes › These devices touched the lunar surface first and sent signals to the Lunar Module to shut down its engine.

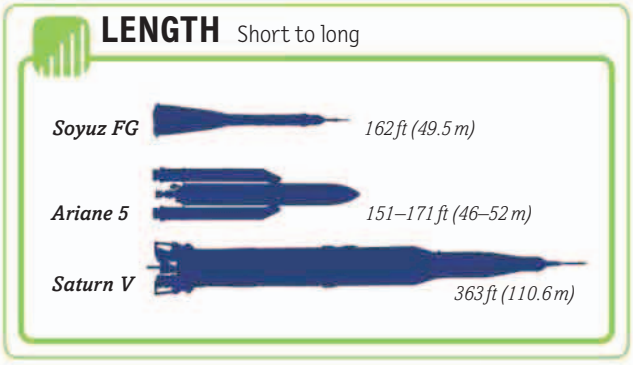
Forward hatch › The approximately 32 in (81 cm) square hatch was used by astronauts to leave the Lunar Module.

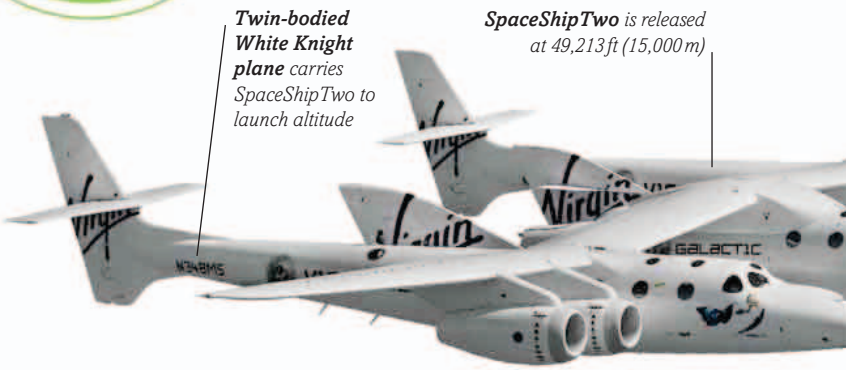
Leg with ladder

Launch vehicles



Saturn V's five rocket engines burned **3,358 gal** (12,710 liters) of fuel per second.





Enormous power is needed to overcome gravity and travel into space—so satellites and spacecraft are propelled by launch vehicles, with rocket engines and their own fuel supply. While rockets can only be used once, space shuttles are reusable.

To carry heavy cargos into space multistage launch vehicles are used, such as the two-stage **Long March 2F**, which carried the Shenzhou spacecraft in 2003, and the **Ariane 5s**, which have made more than 75 successful launches. Each stage of a launch vehicle has its own

rocket engines, and falls away after its fuel is exhausted, leaving the remaining smaller, lighter vehicle to continue. The biggest lifter among current launch vehicles is the **Delta IV Heavy**, which can carry 31-ton loads into Earth orbit. This is just a quarter of the load carried by the three-stage **Saturn V**, used for the Apollo Moon landings. Space planes, such as the **Space Shuttle *Discovery*** and the **SpaceShipTwo**, are powered by rocket engines but use their wings to glide back to the Earth after their mission.

Space probes

Lunokhod 1
Russia 1970

Eight wheels were remotely controlled from Earth

Pioneer 10 USA 1972

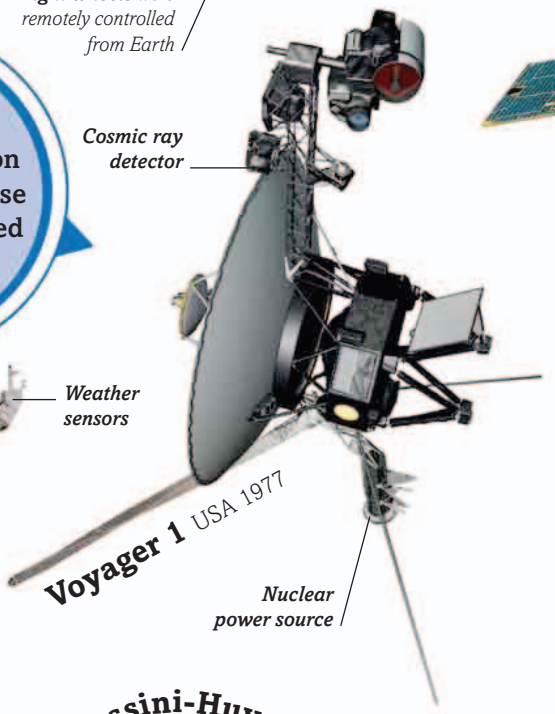
Power supply

Radio antenna for sending and receiving information

Radio dish 8 ft 9½ in (2.7 m) in diameter

9-ft-9-in- (3-m-) long boom

Voyagers 1 and 2 carry a disc of information about Earth, in case they are discovered by **aliens!**



Cosmic ray detector

Weather sensors

Voyager 1 USA 1977

Nuclear power source

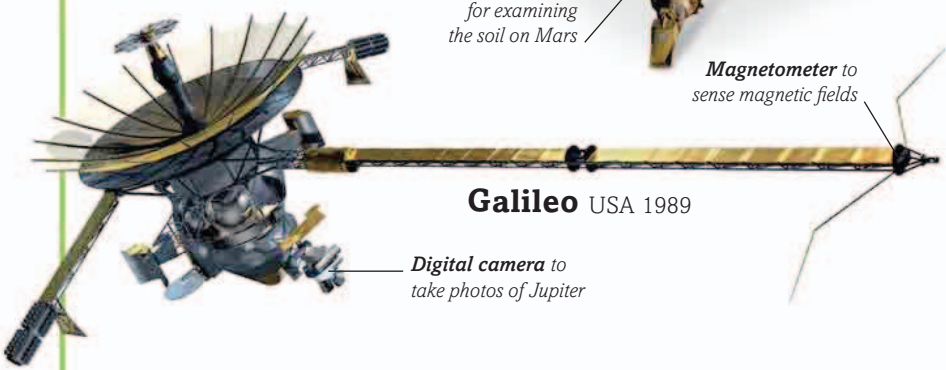
Viking 1 USA 1975

Galileo finally crashed into Jupiter's atmosphere at **30 miles** (48 km) **per second**.

Landing legs contain temperature sensors

Robot arm for examining the soil on Mars

Cassini-Huygens
Multinational 1997



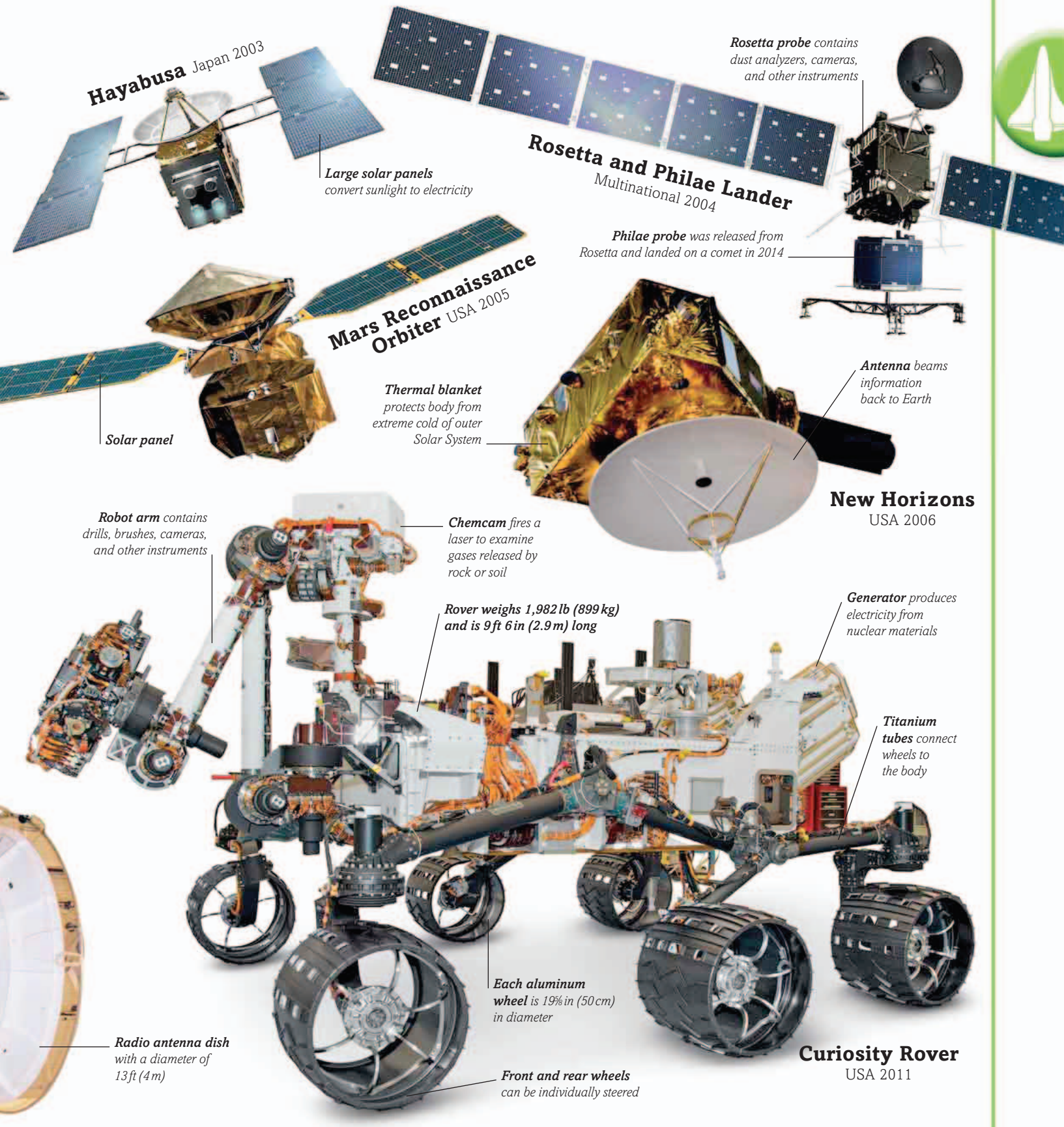
Magnetometer to sense magnetic fields

Galileo USA 1989

Digital camera to take photos of Jupiter

Space probes are robotic, unmanned craft that explore planets, moons, asteroids, and comets, and send information and images back to Earth using radio waves. The work of these probes has helped us to understand our solar system.

Probes can fly past, orbit, or land on their target. **Viking 1** was the first long-term probe to land on Mars, sending back data until 1982. **Lunokhod 1** was the first successful rover, traveling 6.5 miles (10.5 km) around the moon, while the **Curiosity Rover** continues to analyze



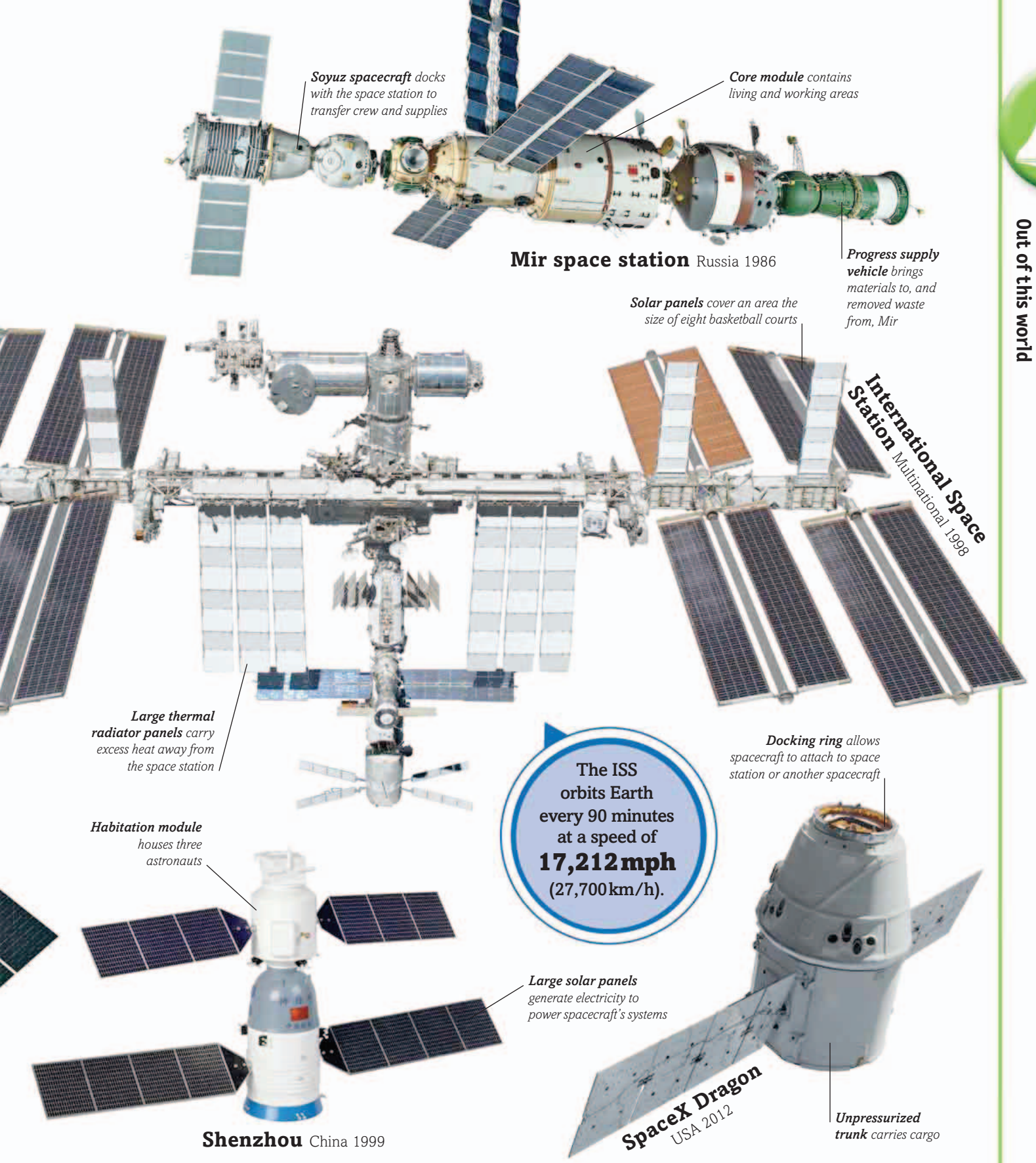
Mars's rock and soil with its built-in laboratory. **Pioneer 10** became the first probe to travel beyond the asteroid belt, when it flew toward Jupiter. Later, however, **Galileo** orbited the planet 34 times sending back many photos and measurements during its 14-year mission. Some probes have traveled even farther. **New Horizons** reached Pluto in 2015, after a 9½ year journey, while **Voyager 1**, launched in 1977, is now more than 11.8 billion miles (19 billion km) away from the Earth and, with Voyager 2 and Pioneers 10 and 11, has left our solar system.

Out of this world

After losing one of its solar panels, astronauts erected a large **sunshade** to keep Skylab cool.

Fewer than 600 people have traveled into space. The first astronauts, known as cosmonauts in Russia, orbited Earth in tiny, one-person space capsules. Later astronauts traveled to the Moon, and to orbiting space stations, where they could live and work.

In 1961, Yuri Gagarin became the first spaceman, with a 108-minute flight in the cramped 7-ft 6-in (2.3-m) capsule of a **Vostok 1** spacecraft. A month later, the USA sent Alan Shepard into space on board **Mercury**. Until space stations were built, early manned missions were short.



Mir space station Russia 1986

International Space Station Multinational 1998

The ISS orbits Earth every 90 minutes at a speed of **17,212 mph** (27,700 km/h).

Shenzhou China 1999

SpaceX Dragon USA 2012

Three crews, with three members in each, lived in the **Skylab** space station for a total of 171½ days, performing 300 experiments. Cosmonauts inhabited the **Mir Space Station** for 12½ years, with Valeri Polyakov spending a record-breaking 437 days, 18 hours in a row. Mir was the first space station to be built from modules that were put together in space. The biggest space station to date is the **International Space Station** (ISS), which needed more than 100 spaceflights, and 1,000 hours of space walks, to assemble. It has been manned since 2000.


Endeavour

LIFTOFF! More than two thousand tons of spacecraft and fuel head into space as space shuttle *Endeavour* thunders out of the launch pad in 2009 at the Kennedy Space Center in Florida. From 1982 to 2011, shuttles made more than 130 successful spaceflights.

Each of a shuttle's two large, solid rocket boosters holds 100,000 lb (450,000 kg) of fuel, which is used up in the first two minutes. The shuttle's main engines continue burning, using all of the 530,000 gal (two million liters) of fuel held in the 157-ft- (48-m-) long orange, external fuel tank by eight minutes after launch, when the shuttle is traveling more than 16,800 mph (27,000 km/h). This mission carried seven astronauts to the International Space Station, returning to Earth 17 days later.

GLOSSARY

Accelerate
To speed up and go faster.

Aerobatics
Acrobatics in the air, performed by aircraft for entertainment as well as in competitions.

Ailerons
Hinged surfaces, usually on an aircraft's wing, that can be raised or lowered to help an aircraft roll or turn.

Alloy
A mixture of two or more elements, at least one of which is a metal. Alloys often have useful properties that differ from those of the elements from which they are made.

Amphibious
A vehicle that can travel both on land and in water.

Articulated train
A train with cars linked together by a single, pivoting joint.

Autogiro
An aircraft with both a main rotor, for lift, and a propeller, to give forward thrust.

Battery
A store of chemicals in a case that, when connected to a circuit, supplies electricity.

Boiler
The part of a steam engine in which steam is produced.

Bow
The forward part of a vessel.

Bowsprit
A spar (pole) that extends forward from a ship's bow.

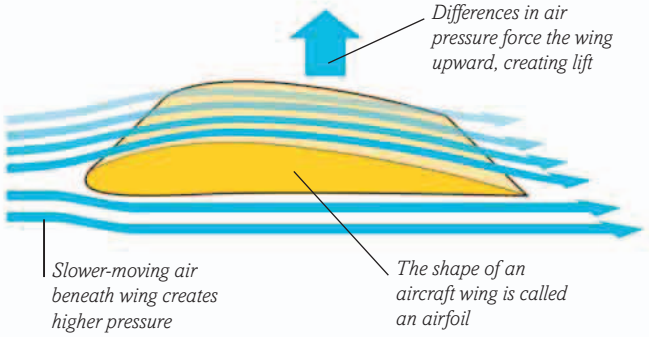
Bridge
The part of a ship from where the captain controls the vessel.

Buffer
A shock-absorbing pad that cushions the impact of rail vehicles as they come together.

Bumper
A metal, rubber, or plastic bar fitted along the front and, sometimes, the back of a vehicle to limit damage if it bumps into something.

Cab
The part of a train or truck where the driver sits and controls the vehicle.

How wings work



Lift
As the curved wing moves through the air, the air passing over the wing moves faster than the air passing beneath. Fast-moving air has a lower pressure. It is the slower, high-pressure air beneath the wing that forces it upward.

Class
A group of locomotives built to a common design.

Convoy
A group of ships or vehicles travelling in formation.

Coupling
The parts, or mechanism, that allow railroad locomotives to be joined together.

Derailleur
The part of a bike that moves the bicycle chain from one gear wheel to another when the rider changes gear.

Destroyer
A small, fast warship armed with guns, torpedoes, or guided missiles.

Diesel
A type of fuel made from oil used in many vehicle engines.

Disk brakes
A type of brake that uses pads to press against a turning disk, creating friction to slow the vehicle down.

Drag
A force of resistance on a vehicle as it moves through air or water, slowing it down.

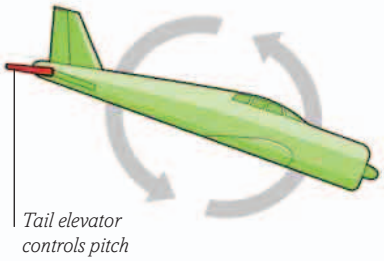
Drone
Also known as an Unmanned Aerial Vehicle (UAV), a flying machine that either controls itself or is controlled remotely by a human operator.

Electromagnets
Magnets that are powered by electricity and can be switched on or off.

Elevator
A control surface on an aircraft that causes the plane to raise or lower its nose and climb or dive.

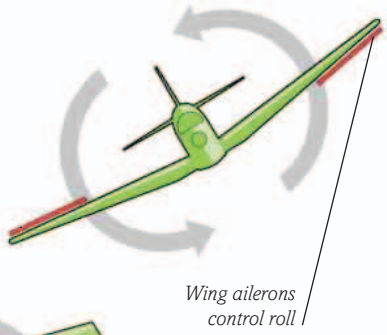
Excavator
A vehicle used at building sites to dig holes using a

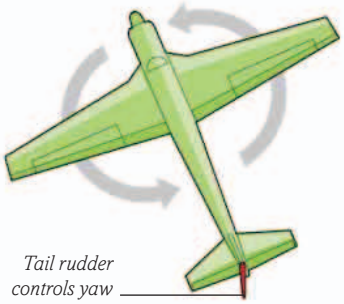
How aircraft climb or dive



Pitch
To pitch (climb or dive), the pilot pushes or pulls the control column, raising or lowering the elevator flaps on the plane.

Roll
To roll, the pilot moves the control column to the left or right, which raises the ailerons on one wing and lowers them on the other.





Yaw
To yaw (turn) left or right, the pilot turns the upright rudder on the airplane's fin.

steel bucket attached to a long arm.

Exhaust
A tube that channels waste gases away from a vehicle's engine and out into the open air.

Firebox
The section at the rear of a steam locomotive boiler where the fuel is burned to heat the water in the boiler.

Flaps
Moveable parts of the rear edge of a wing that are used to increase lift at slower air speeds.

Fly-by-wire
An electronic flight control system used in aircraft instead of mechanical or machine-operated controls.

Foremast
The mast nearest the front of a ship.

Four-wheel drive (4WD)
Where power from the engine is used to turn both the front and back wheels of a vehicle.

Freight
Goods transported in bulk by truck, train, ship, or aircraft.

Friction
The force that slows movement between two objects that rub together. Brakes create lots of friction to slow down a vehicle.

Fuselage
The main body of an aircraft, to which the wings and tail are attached.

Galley (ship)
A fighting ship propelled by oars, and sometimes sails, used in the past in the Mediterranean Sea.

Gear
Toothed wheels that are used in trucks and cars to change the amount of speed or force used to turn wheels.

Generator
A machine that creates electricity.

GPS
Short for global positioning system, this refers to a navigation system that uses signals from a group of space satellites to determine a vehicle's position on Earth's surface.

Hatchback
A small car with a rear door and window covering the trunk area.

Hood
A body panel, usually made of metal, that can open to reveal the vehicle's engine.

Horsepower (hp)
A commonly used measure of the power of a vehicle's engine.

Hull
The main body of a boat or a ship.

Hybrid
A vehicle that has both a gas engine and a second source of power, such as an electric motor.

Hydraulics
A system that uses liquid to transfer force from one place to another, to operate a vehicle's brakes, for example.

Internal combustion engine
A type of engine in which fuel and air are mixed and burned (combusted) inside cylinders to produce power.

Lift
The force created by air moving over a wing or rotor blade to keep an aircraft rising through the air.

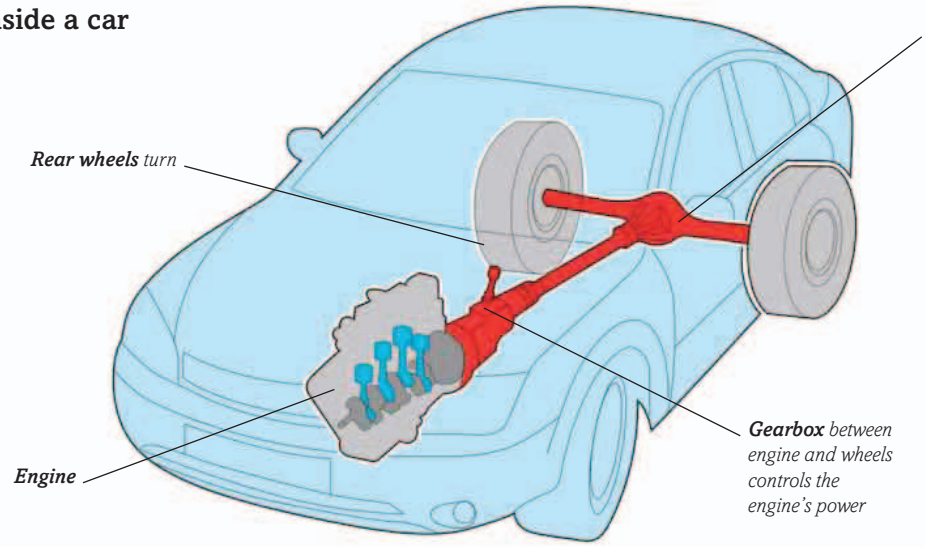
Locomotive
A wheeled vehicle used for pulling trains. Electric locomotives rely on electricity provided by an external source, while steam and diesel locomotives generate their own power.

Maglev train
Short for magnetic levitation, a train that works by being raised above special tracks and moved forward by the power of electromagnets.

Motocross
A type of motorcycle sport where riders race around laps of a cross-country course full of bumps and dips.

Ducati 916SPS

Inside a car



Engine and gearbox
A car engine is an internal combustion engine. The gearbox alters the engine's power to either help the car move slowly and with more force when climbing hills, or quickly and with less force when on a flat road.

NASCAR
Short for National Association for Stock Car Auto Racing, a popular type of car- and truck-racing competition on tracks in North America.

Off-road
To travel in a vehicle away from roads and over tracks, trails, or open ground.

Orbit
The path of one object around a larger one under the influence of its gravity, such as that of a space probe around a planet.

Outboard motor
A detachable engine mounted on a boat's stern.

Outriggers
Bars that extend out from the side of vehicles, such as cranes or canoes, to provide support and help the vehicle balance.

Payload
The load carried by an aircraft or space launch vehicle, which can include both passengers and cargo.

Pollution
Waste products that reach the air, water, or land and can do damage to the environment or the health of living things.

Probe
An unmanned vehicle travelling into space to a planet, moon, comet, or other body in order to collect information.

Propeller
A set of blades spun by an engine to power a vehicle.

Radar
The system of bouncing radio waves off objects to measure their distance, or to reveal objects that cannot be seen.

Roll bar
A strong frame or tube above the head of a driver or passenger that protects them should the vehicle roll over during an accident.

Roll cage
A strong frame inside a vehicle that protects the people sitting inside.

Rocket engine
An engine that burns fuel along with oxygen or oxidiser (oxygen-producing chemicals) to produce a stream of gases. The rocket engine carries its own supply of oxygen or oxidiser.

Rotor blades
Long, thin airfoils that are spun by a helicopter, or other rotorcraft, to produce lift.

Rudder
A vertical plate or board that can be moved to steer a vessel or help turn an aircraft.

Saddle
The seat on a bicycle, motorcycle, or horse where the rider sits.

Solar panel
A device that converts energy from sunlight into electricity.

Sonar
A system for detecting and locating objects, particularly underwater, using sound waves.

DHR B Class No. 19

Spoiler
A device on a car or aircraft, often shaped like a wing, that alters the airflow around the vehicle to generate more drag or downforce. Often found on race cars, to keep them gripping the ground.

Spokes
The rods or bars that connect the center, or hub, of a wheel with its rim.

Stern
The rear part of a boat or a vessel.

Streamlined
A streamlined object has smooth curves so that air or water flows easily, increasing movement.

Street-legal
A car, motorcycle, or truck equipped with all the features required to make it suitable for use on public roads.

Suspension
A system of springs and shock absorbers on a vehicle to help give a smooth ride over bumps and dips.

Supersonic
To fly faster than the speed of sound. The speed of sound is about 768mph (1,236km/h) at sea level.

Switcher
A small locomotive used for moving wagons or train cars around a railroad yard. Also known as a shunter.

Thrust
The force that pushes a powered aircraft through the air, usually generated by an engine.

Tiller
A horizontal bar or handle attached to the rudder of a boat to allow a sailor to steer it.

Ton
A unit of measurement equal to 2,000lb (907.2kg).

Torpedo
A self-propelled underwater weapon with an explosive warhead that is launched from a ship or submarine and travels toward a set target.

Trunk
A space for storage in a car.

Turbocharger
A device that uses waste gases to boost an engine's power.

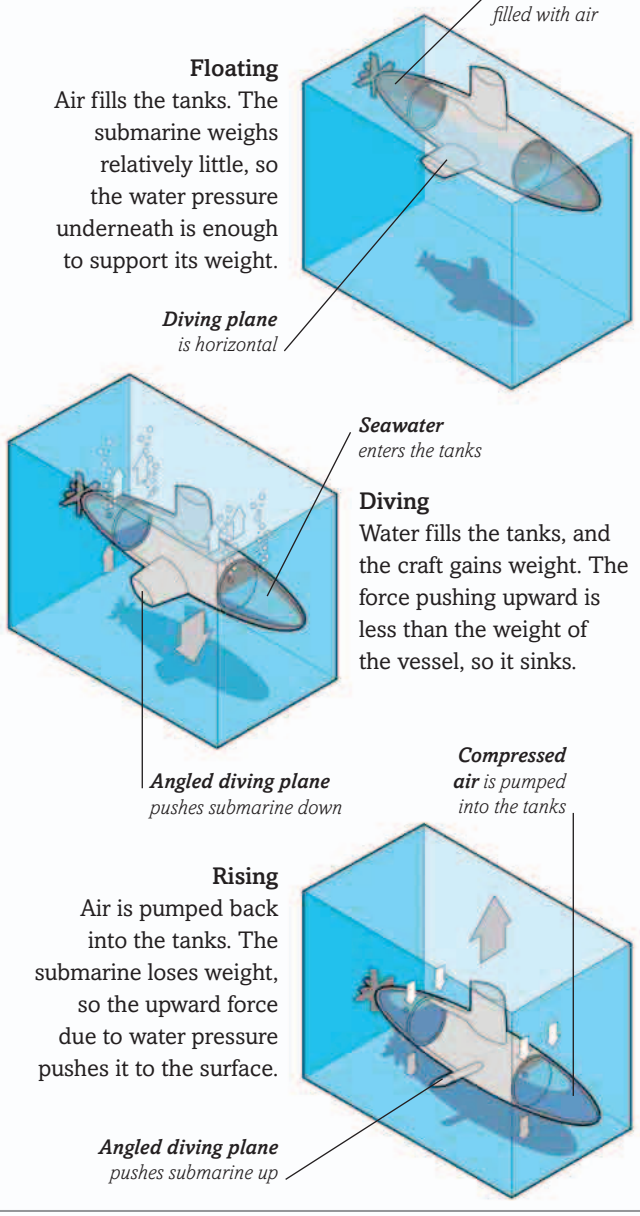
Waterline
The level normally reached by the water on the side of a ship.

Wheelhouse
The part of a ship or boat that holds the ship's wheel, which is used for steering the vessel. In larger ships, the wheelhouse is part of the structure known as the bridge.

VTOL aircraft
Short for vertical takeoff and landing, VTOL refers to aircraft that can use their thrust to head straight up into the air like a helicopter, and so do not require a long runway.

Yard
A long pole, or spar, attached to a ship's mast to which the top of a square sail is fixed.

How a submarine dives



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Tony Dowden (b). 59 **Dorling Kindersley:** Alan Purvis (cla); Michael Delaney (tl); Wayne MacGowan (tr); Phil Davies (clb). **ECOSSE Moto Works, Inc.:** (clb/Ecosse). **Honda (UK):** (crb). **MV Agusta Motor SpA:** (cr). 60-61 **Giles Chapman Library**. 62 **Alamy Images:** Werner Dieterich (cl). 63 **Dorling Kindersley:** Colin Laybourn / P&A Wood (tr); National Motor Museum, Beaulieu (tl); Haynes International Motor Museum (b). **Getty Images:** Print Collector (cl). 64-65 **Getty Images:** ullstein bild / Robert Sennecke. 66 **Alamy Images:** pbpgalleries (crb). **Art Tech Picture Agency:** (clb). **Corbis:** Car Culture (c). **Dorling Kindersley:** Ivan Dutton (br). 67 **Dorling Kindersley:** National Motor Museum, Beaulieu (tl). **Louwman Museum-The Hague:** (crb). 68 **Dorling Kindersley:** Colin Spong (clb); The Titus & Co. Museum for Vintage & Classic Cars (c). **Louwman Museum-The Hague:** (tr). 69 **Alamy Images:** Tom Wood (c). **Art Tech Picture Agency:** (b). **Dorling Kindersley:** National Motor Museum, Beaulieu (t). 70 **Alamy Images:** Esa Hiltula (cl). **Dorling Kindersley:** The Titus & Co. Museum for Vintage & Classic Cars (cla). 70-71 **Dorling Kindersley:** The Titus & Co. Museum for Vintage & Classic Cars (t). 71 **Corbis:** Car Culture (clb). 72 **Alamy Images:** Phil Talbot (cl). 73 **Dorling Kindersley:** National Motor Museum, Beaulieu (tr). **Getty Images:** Heritage Images (crb). 74-75 **Alamy Images:** ImageGB (t). **Courtesy Mercedes-Benz Cars, Daimler AG:** (b). 74 **Alamy Images:** pbpgalleries (clb). 75 **Alamy Images:** Tribune Content Agency LLC (c). **Dreamstime.com:** Warren Rosenberg (ca). **Courtesy of Volkswagen:** (cr). 76-77 **Corbis:** Transtock. 78-79 **Dreamstime.com:** Len Green (c). 78 **Alamy Images:** Mark Scheuern (clb). **Art Tech Picture Agency:** (ca). **Suzuki Motor Corporation:** (c). 79 **Art Tech Picture Agency:** (cra, tr). 80 **Alamy Images:** Buzz Pictures (clb); ZUMA Press, Inc (cla). **Dorling Kindersley:** Chris Williams (c). **Louwman Museum-The Hague:** (tr). 80-81 **Alamy Images:** Mark Scheuern (c). **Getty Images:** Jason Kempin (crb). 81 **Dreamstime.com:** Ermess (crb). **Getty Images:** UK Press / Justin Goff (tl). **Rex Features:** Andy Willsheer (ca). **Terrafugia/www.terrafugia.com:** (c). **Toyota (GB) PLC:** (crb/Toyota FV2). 82-83 **WATERCAR**. 84-85 **Art Tech Picture Agency:** (c). 85 **Alamy Images:** Motoring Picture Library (cr). 86-87 **Alamy Images:** Mark Scheuern (c). 86 **Art Tech Picture Agency:** (crb). **LAT Photographic:** (cl). **Giles Chapman Library:** (cla, cr). **Louwman Museum-The Hague:** (tr). 87 **Corbis:** Car Culture (ca). **Volvo Car Group:** (tr). 88 **Alamy Images:** Phil Talbot (b). 89 **Alamy Images:** Motoring Picture Library (ca). **Dorling Kindersley:** Brands Hatch Morgans (crb); Gilbert and Anna East (c). 90 **Alamy Images:** West Country Images (cla). **Dorling Kindersley:** National Motor Museum, Beaulieu (tr, crb). **Louwman Museum-The Hague:** (cb). 90-91 **Alamy Images:** Shaun Finch - Coyote-Photography.co.uk (b). 91 **Giles Chapman Library:** (tl). **Malcolm McKay:** (cra). **Renault:** (crb). **Tata Limited:** (cr). 92-93 **Alamy Images:** KS_Autosport. 94 **Dorling Kindersley:** Peter Harris (tr). **www.mclaren.com:** (c). 95 **© 2015 Hennessey Performance:** (crb). **Dreamstime.com:** Swisshippo (clb). 96 **Dorling Kindersley:** The Titus & Co. Museum for Vintage & Classic Cars (t). **Dreamstime.com:** Ddcoral (cla). 97 **Art Tech Picture Agency:** (cra). **Dreamstime.com:** Olga Besnard (cr). 98 **Giles Chapman Library:** (cr). **Courtesy Mercedes-Benz Cars, Daimler AG:** (cl). 98-99 **Flock London:** (cb). 99 **Corbis:** Bettmann (tr); Reuters / Kieran Doherty (c); Car Culture (clb). **Getty Images:** Science & Society Picture Library (tl). 100-101 **Corbis:** Leo Mason. 104 **Alamy Images:** Car Collection (clb). **Corbis:** Ecoscene / John Wilkinson (crb). **Dorling Kindersley:** Milestone Museum (tr, cla). 105 **Alamy Images:** Colin Underhill (t). **Dorling Kindersley:** DAF Trucks N.V. (c); DaimlerChrysler AG (clb). 106 **Dorling Kindersley:** Yorkshire Air Museum (cla); The Tank Museum (tr). 107 **Daimler AG:** (tr). **Dorling Kindersley:** James River Equipment (c). **Max-Holder:** (crb). 108-109 **Corbis:** Reuters / Rick Fowler. 110 **Corbis:** Demotix / pqneiman (tr). **Dorling Kindersley:** Newbury Bus Rally (cl, b). **Rex Features:** Roger Viollet (tl). 110-11 **Foremost, http://foremost.ca/:** (c). 111 **Alamy Images:** Oliver Dixon (cb). **Corbis:** Reuters / Brazil / Stringer (t). 112-113 **Dorling Kindersley:** Chandlers Ltd. 114 **Dorling Kindersley:** Paul Rackham (cl, clb); Roger and Fran Desborough (cla, cr). **David Peters:** (crb). 114-115 **Dorling Kindersley:** The Shuttleworth Collection (t). 115 **AGCO Ltd:** (cra). **Dorling Kindersley:** David Wakefield (t); Doubleday Holbeach Depot (cl); Lister Wilder (cr). **John Deere:** (clb). **New Holland Agriculture:** (crb). 116 **Dorling Kindersley:** David Bowman (t); Doubleday Swineshead Depot (cl). **John Deere:** (clb). 116-117 **Dorling Kindersley:** Doubleday Swineshead Depot (b). 117 **AGCO Ltd:** (tl). **Hagie Manufacturing Company:** (crb). **New Holland Agriculture:** (cla, tr, cr). 118-119 **Action Plus**. 120-121 **Getty Images:** AFP / Viktor Drachev (c). 121 **Dorling Kindersley:** DaimlerChrysler AG (tl); James River Equipment (crb). 122 **Dorling Kindersley:** Royal Armouries, Leeds (cra); The Second Guards Rifles Division (cr); The Tank Museum (cla, cl, tr). 122-123 **Dorling Kindersley:** The Tank Museum (b). 123 **Dorling Kindersley:** Royal Armouries, Leeds (cl, cra); The Tank Museum (tl, tr, crb, crb/Leopard C2). 124-125 **Dorling Kindersley:** B&O Railroad Museum. 126 **Dorling Kindersley:** Railroad Museum of Pennsylvania (c); The Science Museum, London (tr, clb); The National Railway Museum, York (cb). **Science & Society Picture Library:** National Railway Museum (cla). 126-127 **Dorling Kindersley:** The National Railway Museum, York / Science Museum Group (c). 127 **colour-rail.com:** (cra). **Dorling Kindersley:** B&O Railroad Museum (tl, tr, br); The National Railway Museum, York (cr). 128 **Dorling Kindersley:** B&O Railroad Museum (ca); The National Railway Museum, New Dehli (cb). 128-129 **Dorling Kindersley:** Adrian Shooter (cb); The National Railway Museum, York (ca, cb/Mallard). 129 **Dorling Kindersley:** Railroad Museum of Pennsylvania (br). 130-131 **Corbis:** Milepost 92 1 / 2 / W.A. Sharman. 132-133 **Dorling Kindersley:** Ribble Steam Railway / Science Museum Group. 134 **Dorling Kindersley:** The Musee de Chemin de Fer, Mulhouse (tl). **Steam Picture Library:** (bl). 134-135 **Dorling Kindersley:** B&O Railroad Museum (bc); Harzer Schmalspurbahnen (c, tc). 135 **Corbis:** Bettmann / Philip Gendreau (tr). **Dorling Kindersley:** Virginia Museum of Transportation (cr, crb). 136 **Dorling Kindersley:** B&O Railroad Museum (cl, cb); Virginia Museum of Transportation (cla). 136-137 **Dorling Kindersley:** Ribble Steam Railway / Science Museum Group (t); Virginia Museum of Transportation (ca). **Keith Fender:** (c). 137 **colour-rail.com:** (crb). **Dorling Kindersley:** The DB Museum, Nurnburg, Germany (tr). **Keith Fender:** (clb). 138 **Dorling Kindersley:** Didcot

Railway Centre (tl); The National Railway Museum, York / Science Museum Group (cl); Railroad Museum of Pennsylvania (clb); The Verkehrshaus der Schweiz, Luzern, Switzerland (c). 138-139 **Dorling Kindersley:** Ffestiniog & Welsh Highland Railways (tr). 139 **Dorling Kindersley:** B&O Railroad Museum (c); Didcot Railway Centre (cr); Eisenbahnfreunde Traditionsbahnbetriebswerk Stassfurt (clb). **Keith Fender:** (crb). 140 **Dorling Kindersley:** B&O Railroad Museum (tl); Eisenbahnfreunde Traditionsbahnbetriebswerk Stassfurt (crb); Railroad Museum of Pennsylvania (clb); The National Railway Museum, York (ca). 140-141 **Dorling Kindersley:** The National Railway Museum, India (t). 141 **Dorling Kindersley:** DB Schenker (b); The Musee de Chemin de Fer, Mulhouse (tr); Railroad Museum of Pennsylvania (cra); Eisenbahnfreunde Traditionsbahnbetriebswerk Stassfurt (cb). 142 **Alamy Images:** Kevin Foy (cr); Colin Underhill (tl). **colour-rail.com:** (cl). **Keith Fender:** (cra). **Brian Stephenson/RAS:** (b). 143 **Alamy Images:** epa european pressphoto agency b.v (crb); Iain Masterton (tr). **Dorling Kindersley:** Hitachi Rail Europe (cra). **Dreamstime.com:** Tan Kian Yong (cl). **Keith Fender:** (cr, clb). 144-145 **Alamy Images:** Stock Connection Blue. 146 **Alamy Images:** Danita Delimont (ca); Alan Moore (clb). **Brian Stephenson/RAS:** (clb/berlin u-bahn). 146-147 **Dreamstime.com:** Alarico (cb). **Siemens AG:** (t). 147 **Alamy Images:** dpict (cl); Iain Masterton (tr). **Bombardier Transportation, Bombardier Inc.:** (cr). **WSW mobil GmbH:** büro+staubach (crb). 148 **Alamy Images:** Jon Sparks (clb). **Dreamstime.com:** Yulia Belousova (crb). 149 **Alamy Images:** RIA Novosti (br). **CAF, CONSTRUCCIONES Y AUXILIAR DE FERROCARRILES, S.A.:** (cra). **Image supplied by Transport for Greater Manchester and taken by Lesley Chalmers.:** (tl). 150-151 **Corbis:** Stringer / India / Reuters. 152-153 **Alamy Images:** Tracey Whitefoot. 154 **Dorling Kindersley:** Exeter Maritime Museum, The National Maritime Museum, London (cl); National Maritime Museum, London (b). **National Maritime Museum, Greenwich, London:** (cra). 155 **Dorling Kindersley:** Exeter Maritime Museum, The National Maritime Museum, London (ca, clb); National Maritime Museum, London (t). **National Maritime Museum, Greenwich, London:** (c, b). 156 **Dorling Kindersley:** National Maritime Museum, London (cla, bl, cr, crb). 156-157 **Dorling Kindersley:** Exeter Maritime Museum, The National Maritime Museum, London (ca). 157 **Alamy Images:** Eye Ubiquitous (cr). **Dorling Kindersley:** Maidstone Museum and Bentliff Art Gallery (t); National Maritime Museum, London (crb). **National Maritime Museum, Greenwich, London:** (clb). 158-159 **Lane Jacobs**. 160-161 **Dorling Kindersley:** National Maritime Museum, London. 162 **Dorling Kindersley:** National Maritime Museum, London (clb); The Science Museum, London (cla). **Getty Images:** DEA / G. Nimatalah (crb). **Science & Society Picture Library:** (cr). 162-163 **Dorling Kindersley:** National Maritime Museum, London (t). 163 **Dorling Kindersley:** Pitt Rivers Museum, University of Oxford (cb). **National Maritime Museum, Greenwich, London:** (crb). 164 **Dorling Kindersley:** The National Maritime Museum, London (cla, c); Virginia Museum of Transportation (clb). **Rex Features:** Ilpo Musto (crb). 164-165 **Dorling Kindersley:** National Maritime Museum, London (c). 165 **Dorling Kindersley:** National Maritime Museum, London (cb); National Maritime Museum, London (cr). **The Fram Museum, http://www.frammuseum.no/:** (tr); **Michael Czytko, www.modelships.de:** (tl). 166-167 **Dorling Kindersley:** National Maritime Museum, London (ca). 166 **John Hamill:** (tl). **National Maritime Museum, Greenwich, London:** (bl). **www.modelshipmaster.com:** (crb). 167 **Dorling Kindersley:** Fleet Air Arm Museum (c). **National Maritime Museum, Greenwich, London:** (tl, br). **www.modelshipmaster.com:** (clb). 168-169 **Gilles Martin-Raget / www.martin-raget.com**. 170-171 **National Maritime Museum, Greenwich, London**. 172 **Dorling Kindersley:** National Maritime Museum, London (cla, cb). **Getty Images:** Science & Society Picture Library (t). 172-173 **Getty Images:** Science & Society Picture Library (c). **National Maritime Museum, Greenwich, London:** (cb). 173 **National Maritime Museum, Greenwich, London:** (t, cr, cb, crb). 174 **Dorling Kindersley:** National Maritime Museum, London (clb); RNLI - Royal National Lifeboat Institution (cr). **National Maritime Museum, Greenwich, London:** (cla, cl). 174-175 **National Maritime Museum, Greenwich, London:** (cb). 175 **Dorling Kindersley:** National Maritime Museum, London (c, cb). **National Maritime Museum, Greenwich, London:** (t). 176 **Dorling Kindersley:** National Maritime Museum, London (t). **National Maritime Museum, Greenwich, London:** (ca, clb). 176-177 **Dreamstime.com:** Jhamlin (crb). 177 **National Maritime Museum, Greenwich, London:** (t). **Used with permission of Royal Caribbean Cruises Ltd.:** (c). 178-179 **Corbis:** Joe Skipper / Reuters. 180 **Dorling Kindersley:** Fleet Air Arm Museum (cb); The Fleet Air Arm Museum (cla). **National Maritime Museum, Greenwich, London:** (cl). 180-181 **National Maritime Museum, Greenwich, London:** (c, cb). **SD Model Makers:** (t, ca). 181 **Dorling Kindersley:** Scale Model World (cb). **SD Model Makers:** (cr, tr). 182 **SD Model Makers:** (cla, ca, clb). 182-183 **Dorling Kindersley:** Model Exhibition, Telford (c, crb); Fleet Air Arm Museum (t); USS George Washington and the US Navy (ca). 183 **Alamy Images:** David Acsota Allely (cb). 184 **Alamy Images:** Joel Douillet (cr). **Dorling Kindersley:** Fleet Air Arm Museum (ca, cl). **SD Model Makers:** (cb). 184-185 **Dorling Kindersley:** Fleet Air Arm Museum (t). 185 **Alamy Images:** Jim Gibson (cr); Stocktrek Images, Inc. (cl). **Dorling Kindersley:** Scale Model World (cb). **Press Association Images:** (clb). **SD Model Makers:** (cla). 188 **Dorling Kindersley:** Fleet Air Arm Museum (cb); The Royal Navy Submarine Museum, Gosport (cla); Scale Model World (c). **National Maritime Museum, Greenwich, London:** (tr). **SD Model Makers:** (cra). 188-189 **Dorling Kindersley:** The Fleet Air Arm Museum (b). 189 **Dorling Kindersley:** IFREMER, Paris (cl); Scale Model World (t); The Science Museum, London (cla); Fleet Air Arm Museum (cb). **TurboSquid:** wdc600 (cr). 190-191 **Alamy Images:** Glyn Genin (t). 190 **British Hovercraft Company Ltd.:** (b). **Dorling Kindersley:** Search and Rescue Hovercraft, Richmond, British Columbia (ca). **LenaTourFlot LLC.:** (cl). 191 **123RF.com:** Suttipon Thanarakpong (crb). **Getty Images:** Science & Society Picture Library (cr). **Kawasaki Motors Europe N.V.:** (clb). **Photo used with permission of BRP:** (tr). 192 **123RF.com:** Richard Pross (cr). **Alpacka Raft LLC:** (tr). **Chris-Craft:** (tl). **Dreamstime.com:** Georgesixth (cb). 193 **Hamant Airboats, LLC:** (tl). **National Maritime Museum, Greenwich, London:** (tr, cl). 194-195 **Corbis:** Chen Shaojin / Xinhua Press. 196-197 **Dreamstime.com:** Bigknell. 198-199 **Dorling Kindersley:** Roy Palmer. 200 **Dorling Kindersley:** Musee Air & Space Paris, La Bourget (cl, c, cr); The Real Aeroplane Company (clb). 200-201 **Dorling Kindersley:** The Shuttleworth Collection (b). 201 **Dorling Kindersley:** Musee Air & Space Paris, La Bourget (cra, cl, c); The Planes of Fame Air Museum, Chino, California (t); Nationaal Luchtvaart Themapark Aviodome (cb). 202 **Dorling Kindersley:** Brooklands Museum (cla); The Shuttleworth Collection, Bedfordshire (t); Flugausstellung (cr); The Shuttleworth Collection (b). 203 **Dorling Kindersley:** Fleet Air Arm Museum (t); Nationaal Luchtvaart Themapark Aviodome (c); The Shuttleworth Collection (crb, crb/Avro Triplane). **U.S. Air Force:** (clb). 204-205 **Corbis:** Minnesota Historical Society. 206-207 **Dorling Kindersley:** Brooklands Museum (c); Planes of Fame Air Museum, Chino, California (cb). 206 **Dorling Kindersley:** Musee Air & Space Paris, La Bourget (cl); Flugausstellung (clb). **Richard Bungay(https://www.flickr.com/photos/98961263@N00/):** (tc). 207 **Dorling Kindersley:** Royal Airforce Museum, London (Hendon) (c); Yorkshire Air Museum (t); Planes of Fame Air Museum, Chino, California (crb); The Shuttleworth Collection (b). 208 **Dorling Kindersley:** Royal Airforce Museum, London (Hendon) (ca); The Real Aeroplane Company (tr); B17 Preservation (cl); RAF Museum, Cosford (clb). 208-209 **Alamy Images:** Anthony Kay / Flight (c). **Dorling Kindersley:** Gatwick Aviation Museum (cb). 209 **Dorling Kindersley:** Gatwick Aviation Museum (cra); Ukraine State Aviation Museum (cr, crb). **Getty Images:** Max Mumby / Indigo (t). 210-211 **Dorling Kindersley:** Royal Airforce Museum, London (Hendon) (c). 210 **©2015 National Air and Space Museum Archives, Smithsonian:** (crb). **Alamy Images:** B Christopher (clb). **Dorling Kindersley:** Musee Air & Space Paris, La Bourget (cla, cra, cl). 211 **Alamy Images:** Susan & Allan Parker (cr). **Dorling Kindersley:** Musee Air & Space Paris, La Bourget (tl, tr); Mr R A Fleming, The Real Aeroplane Company (clb); RAF Museum, Cosford (crb). 212 **Dorling Kindersley:** Royal Airforce Museum, London (Hendon) (t, ca); March Field Air Museum, California (cr); Flugausstellung (crb). **Dreamstime.com:** Gary Blakeley (clb). 212-213 **123RF.com. Dorling Kindersley:** Golden Apple Operations Ltd (cb). 213 **Dorling Kindersley:** RAF Coningsby (clb); Yorkshire Air Museum (t); City of Norwich Aviation Museum (cr); Flugausstellung (cl); Midlands Air Museum (ca). **Dreamstime.com:** Eugene Berman (crb). 214-215 **Alamy Images:** A. T. Willett. 216 **Dorling Kindersley:** Flugausstellung (cl); Fleet Air Arm Museum (cla); Brooklands Museum Trust Ltd, Weybridge, Surrey (tr); Gary Wenko (cr); Gatwick Aviation Museum (crb). **Dreamstime.com:** I4lcocl2 (clb). 217 **Alamy Images:** NielsVK (c). **Dorling Kindersley:** Musee Air & Space Paris, La Bourget (crb); Fleet Air Arm Museum (t); Ukraine State Aviation Museum (clb). 218 **Dorling Kindersley:** Planes of Fame Air Museum, Valle, Arizona (tl). 218-219 **Alamy Images:** Steven May (b). 219 **Alamy Images:** Susan & Allan Parker (br). **Dorling Kindersley:** Pima Air and Space Museum, Tuscon, Arizona (tl); The Real Aeroplane Company (tr). 220-221 **Dreamstime.com:** Songallery (cb). 220 **AirTeamImages.com:** (clb/Sud). **Dorling Kindersley:** Flugausstellung (b); Nationaal Luchtvaart Themapark Aviodome (cla, cra). 221 **Dorling Kindersley:** Ukraine State Aviation Museum (t). 222-223 **Alamy Images:** Jim Kidd. 224 **Dorling Kindersley:** Midlands Air Museum (clb, b); RAF Museum, Cosford (c). **Science Photo Library:** Detlev Van Ravenswaay (cla). 224-225 **NASA:** (b). 225 **Alamy Images:** NASA Archive (tr). **Dorling Kindersley:** Flugausstellung (tl); Ukraine State Aviation Museum (c); Yorkshire Air Museum (cb). 226 **Alamy Images:** Thierry GRUN - Aero (t). **Dorling Kindersley:** The Shuttleworth Collection, Bedfordshire (c); The Shuttleworth Collection (crb). **U.S. Air Force:** (clb, b). 226-227 **Alamy Images:** aviafoto (ca); Kevin Maskell (cr). 227 **NASA:** Tony Landis (tr). 228-229 **Dorling Kindersley:** RAF Boulmer, Northumberland. 230 **Dorling Kindersley:** De Havilland Aircraft Heritage Centre (tl); The Museum of Army Flying (crb). 230-231 **aviation-images.com:** (cra). 231 **aviation-images.com:** (cla). **Dorling Kindersley:** Musee Air & Space Paris, La Bourget (tr, crb); RAF Museum, Cosford (ca); Ukraine State Aviation Museum (cb, cr). 232 **Dorling Kindersley:** Norfolk and Suffolk Aviation Museum (tl). 233 **Dorling Kindersley:** Musee Air & Space Paris, La Bourget (cla). **Dreamstime.com:** Patrick Allen (cra). 234 **Dorling Kindersley:** Ukraine State Aviation Museum (cla, cb). 234-235 **Dorling Kindersley:** Ukraine State Aviation Museum. 238 **Corbis:** Imaginechina (r). **Dorling Kindersley:** Bob Gathany (l). **Getty Images:** Bloomberg / David Paul Morris (crb). **NASA:** (cl, c). 239 **Alamy Images:** Konstantin Shaklein (l). **NASA:** (cl, cb); Kim Shiflett (c). **Science Photo Library:** Detlev Van Ravenswaay (r). 240 **Corbis:** Model of the nuclear powered interplanetary probe sent to Jupiter (cla). **NASA:** JPL-Caltech / University of Arizona (c); JPL-Caltech (cr); KSC (crb). **Science Photo Library:** Ria Novosti (tr). 241 **Corbis:** JPL-Caltech (cb). **ESA:** ATG medialab (tr, cra). **Getty Images:** AFP / Akihiro Ikeshita (tl). **NASA:** JPL (cla); The Johns Hopkins University Applied Physics Laboratory LLC (c). 242 **Corbis:** Richard Cummins (c). **Dorling Kindersley:** Bob Gathany (cl). **NASA:** (crb, clb); (tr). 243 **Dorling Kindersley:** ESA (t). **NASA:** (c, crb). 244-245 **NASA:** Sandra Joseph, Kevin O'Connell. 246 **John Deere:** (bl). 247 **Dorling Kindersley:** Beaulieu National Motor Museum (br). 248-249 **Dorling Kindersley:** Adrian Shooter (b). 249 **Dorling Kindersley:** National Maritime Museum, London (tl). 250 **Dorling Kindersley:** The Tank Museum (br). 251 **Dorling Kindersley:** National Maritime Museum, London (tl). 252 **Dorling Kindersley:** National Maritime Museum, London (tl). 253 **Dorling Kindersley:** The Shuttleworth Collection (tl). 254 **Dorling Kindersley:** Hitachi Rail Europe (bl); Paul Rackham