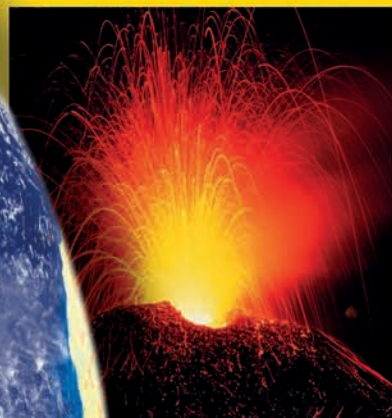
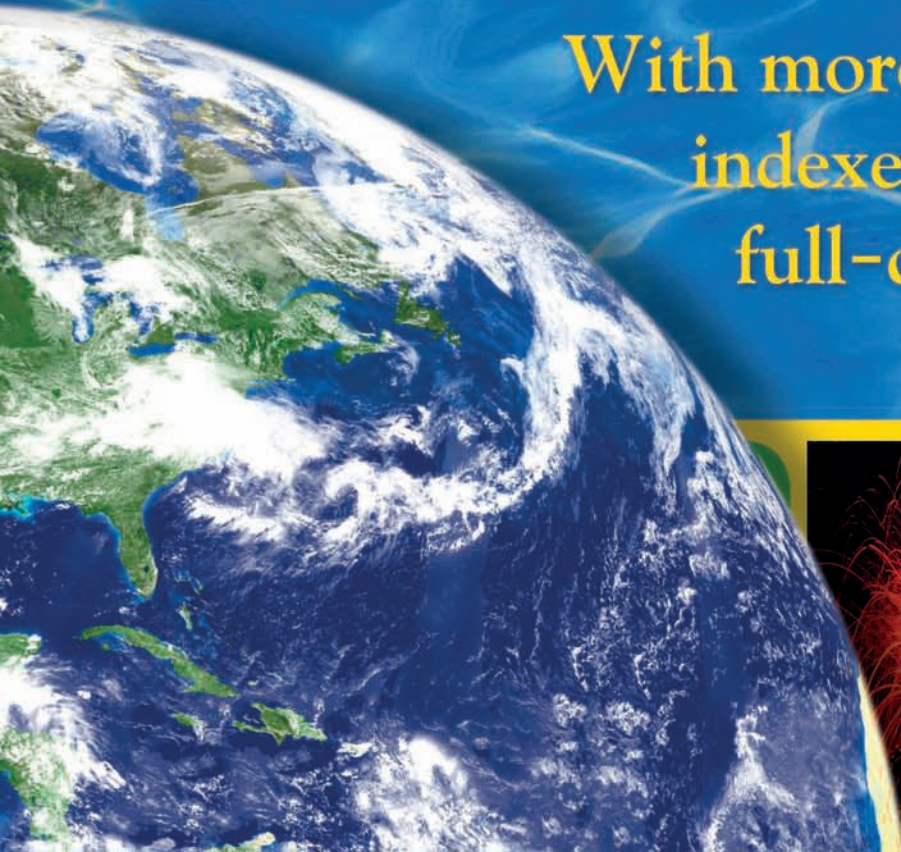


# The *New* Children's Encyclopedia

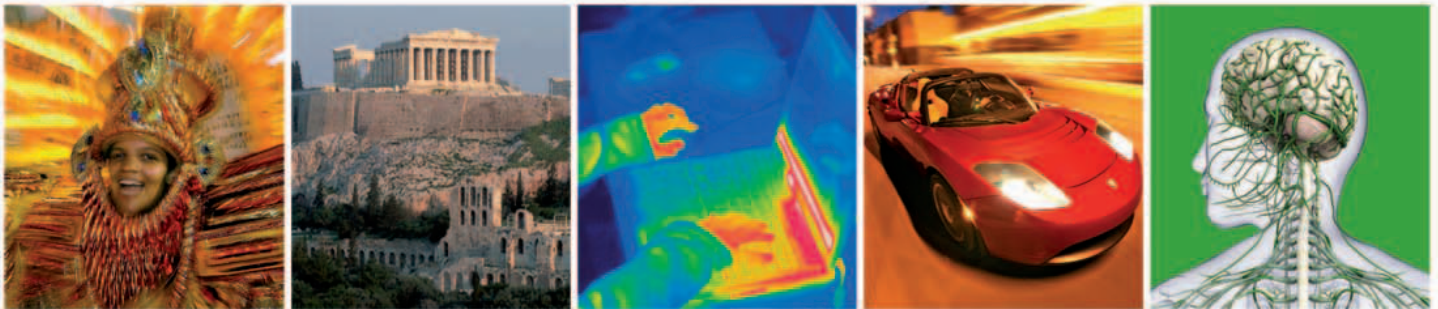
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# The *New* Children's Encyclopedia



DK Publishing





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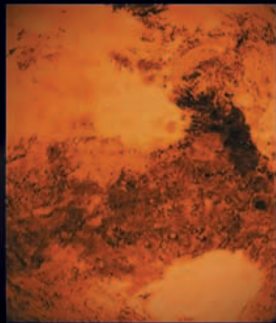
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# Introduction

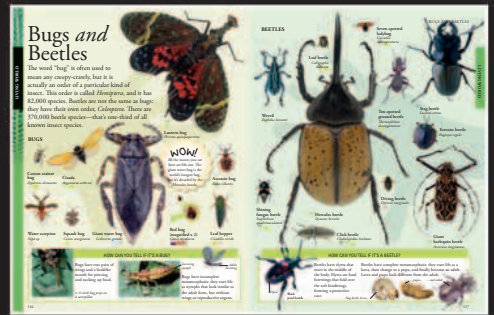
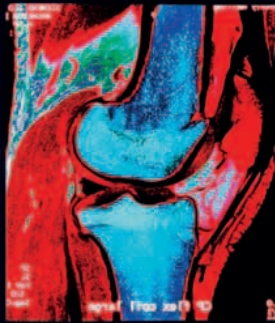


Every child needs a book that answers his or her questions about the world: how it was made, what makes plants grow, why the Sun shines, how the human body works, what happened in the past, and why other countries are different from their own. Properly stimulated, this early thirst for knowledge can become a lifelong process of discovery and understanding. This encyclopedia aims to encourage young readers to make these discoveries for themselves by presenting clear and concise information in an exciting visual manner that draws them in and entices them to read on.

This brand new *Children's Encyclopedia* is divided into thematic chapters. All the major topics are represented: space, Earth science, the environment, animals and plants, countries of the world, culture, history, science and technology, and the human body. Stunning photographs and illustrations accompany the text, which is packed with fascinating facts, timelines, and special features. Cross references lead the reader to related topics that help cover the subject in more depth and from new angles. Unique features focus on items of special interest, such as an orchestra or time zones, or collections of bugs or minerals. With so much to look at and find out about, this book will prove to be a valuable reference that young readers will treasure for years to come.

(👁️ p. 110–111) When you see this symbol in the book, turn to the pages listed to find out more about a subject.

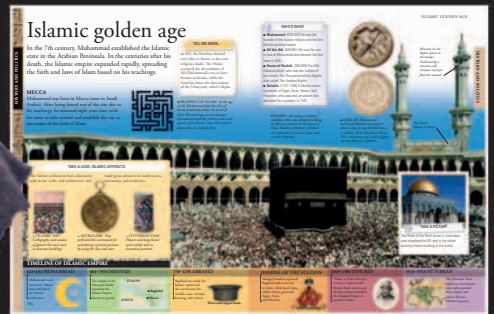




▲ **COLLECTIONS** look at a particular group of things such as beetles and bugs (👁️ p. 116–117), flags, and mammals.



▲ **DETAILED MAPS** accompany features about countries and continents (👁️ p. 128–153). These are packed with facts and figures about the geography, people, and cultures of the region.



▲ **GENERAL ARTICLES** focus on particular topics of interest (👁️ p. 196–197). Many have timelines that chronicle key stages in development, fact boxes, and picture features.



▲ **FACT FILES** take an in-depth look at one topic, such as electric cars (👁️ p. 258–259). They detail all you need to know about the subject.



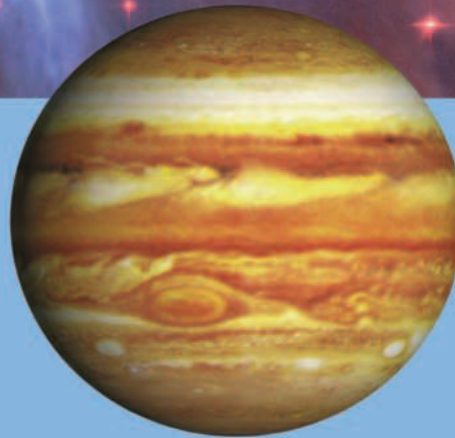


# SPACE

- The universe was born in a Big Bang about 13.7 billion years ago.
- Space begins 60 miles (100 km) above the Earth.
- There are 8 planets, 5 dwarf planets, and 165 known moons in our solar system.
- The Sun is orbited by billions of asteroids, comets, and Kuiper Belt objects.
- The first artificial satellite, Sputnik, was launched by the Soviet Union in 1957.

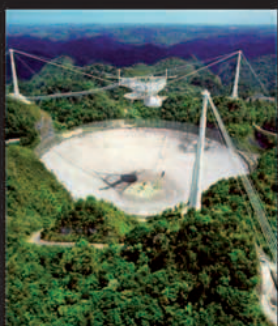


Which star is our nearest star?  
*Find out on pages 12-13*



Which planet is the king of the planets? *Find out on pages 16-17*





*Definition:* **Space** includes the entire universe—planets, moons, stars, and galaxies. Since its birth in the Big Bang, space has been expanding outward continuously.

- About 500 people have flown in space since 1961.
- A teaspoonful of material from a neutron star would weigh 10 billion tons on the Earth.
- A black hole is a region of space where gravity is so strong that nothing can escape.
- The temperature at the center of the Sun is 27,000,000°F (15,000,000°C).
- When a dying star explodes, it releases as much energy as the Sun emits in its lifetime.



When did the Hubble go into orbit? *Find out on pages 20-21*



Which rovers landed on Mars in 2004? *Find out on pages 26-27*

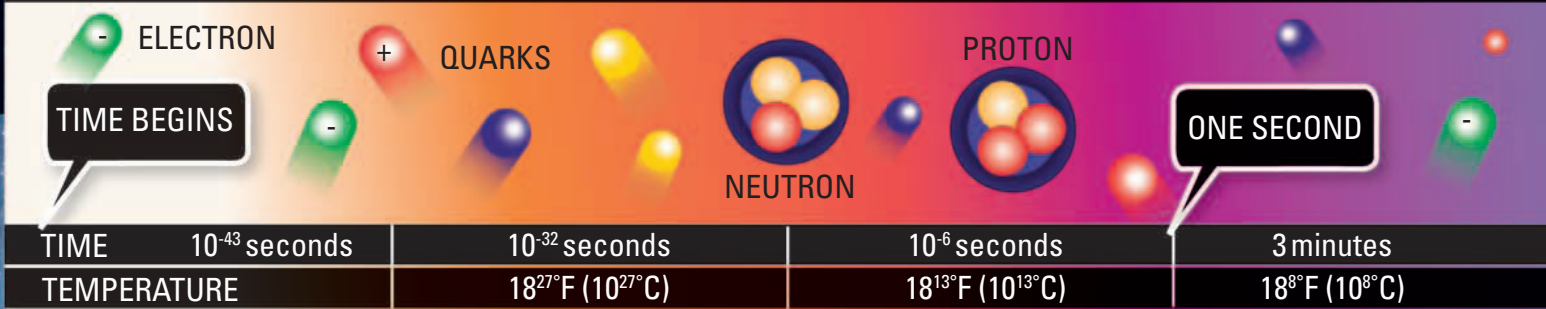




# The universe

The universe is unbelievably huge. It is everything we can touch, feel, sense, measure, or detect. It includes people, plants, stars, galaxies, dust clouds, light, and even time. Scientists believe our universe has existed for almost 14 billion years.

**EXPANDING UNIVERSE**  
Across the visible universe, galaxies are found to be moving away from each other—a little like spots on an inflating balloon. However, it is actually space that is expanding. The farther away from us galaxies are, the faster they seem to be moving.



**1** Moments after the Big Bang, the cosmos goes through a superfast “inflation.” It expands from smaller than an atom to the size of a grapefruit in a tiny fraction of a second.

**2** Postinflation, the universe is a seething, hot soup of electrons, quarks, and other particles.

**3** A rapidly cooling cosmos permits quarks to clump into protons and neutrons.

**4** Still too hot to form into atoms, charged electrons and protons scatter light: the universe is a superhot fog.

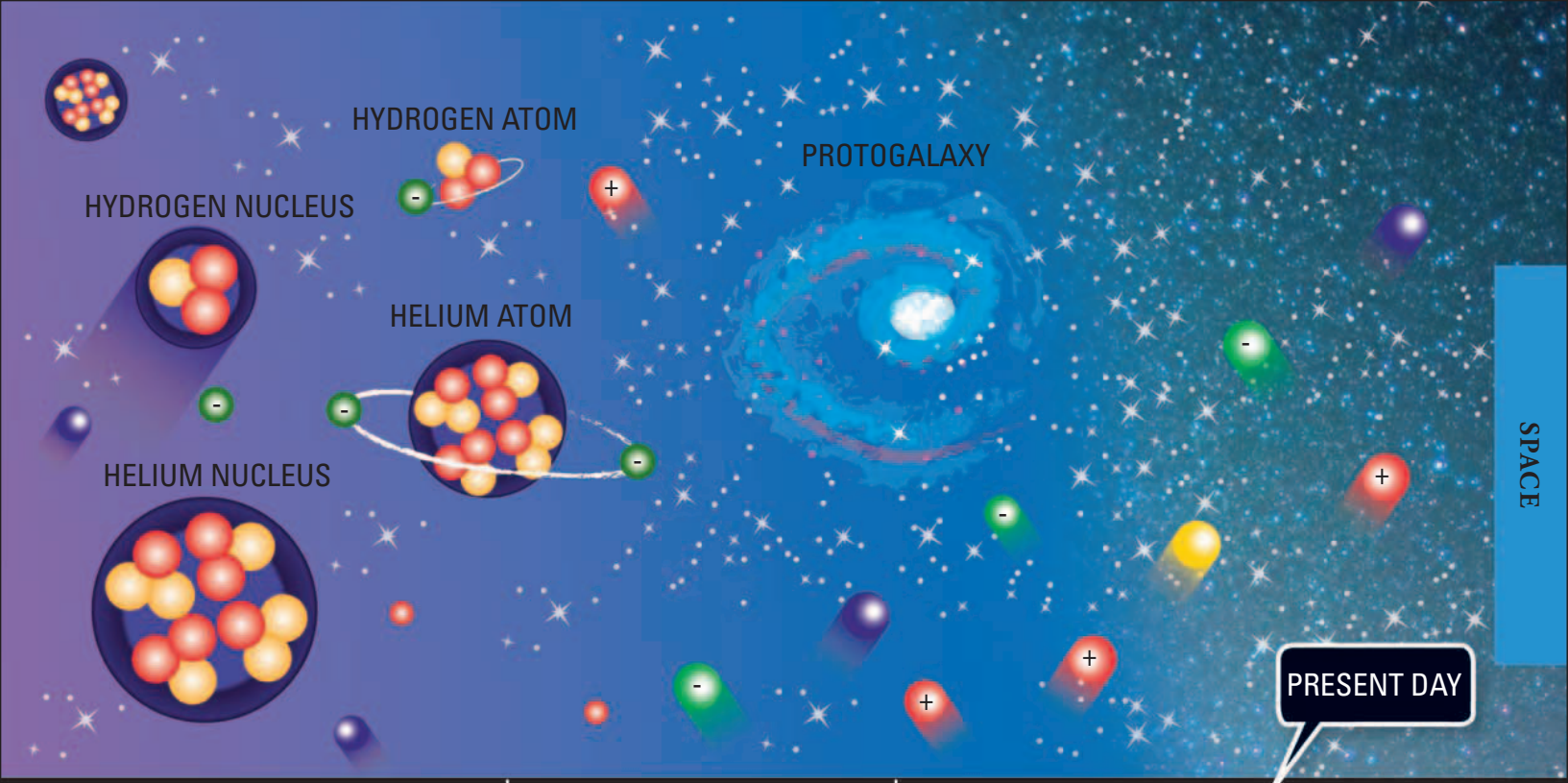
## SPACE FACT FILE

- Light from distant galaxies has taken more than 12 billion years to arrive—so we see them as they were before the Earth was born.
- There are more stars in the universe than there are grains of sand on all of Earth’s beaches.
- In its first second, the universe grew from smaller than an atom to about 1,000 times the size of our solar system today.

**Astronomers** measure distance in light-years. One light-year is the distance light travels in one year. Visible light travels at 186,000 miles/second (300,000 km/second) in space. It takes a long time for light to reach us from distant stars and planets. Telescopes are like time machines, allowing us to see what things looked like in the past.







300,000 years  
18,000°F (10,000°C)

1 billion years  
-325°F (-200°C)

13 billion years  
-450°F (-270°C)

**5** Electrons combine with protons and neutrons to form atoms, mostly hydrogen and helium. Light can finally travel long distances across the universe.

**6** Gravity makes hydrogen and helium gas come together to form clouds where the first stars are born. Larger clouds and groups of young stars form the first galaxies.

**7** As galaxies cluster together under gravity, the first stars die and spew heavy elements into space: these will eventually form into new stars and planets.



◀ In 1974, a coded radio message (right) was sent toward the M13 star cluster from the huge Arecibo radio telescope (left). The message will take about 25,000 years to get there, so we may get a reply 50,000 years from now!

► From the top the symbols represent the numbers from one to ten, some atoms, molecules, DNA, a human, the basics of our solar system and information about the sending telescope.



**WOW!**

Does ET really exist?

The only place known to support life is Earth. But scientists believe that life could exist on other worlds if they possess liquid water and the right temperature. As telescopes become more powerful, scientists expect to find huge numbers of Earth-like planets. Some may support life.



# Galaxies

Scattered across the universe are billions of galaxies, each containing millions or even billions of stars. They come in many different shapes and sizes. Modern telescopes can now see very old galaxies that were born not long after the birth of the universe.

## SHAPES AND SIZES

Some galaxies are “elliptical” or almost round, like huge balls. Some are spirals, with long, curved arms. Many small galaxies are “irregular,” with no special shape. Small galaxies may contain a few million stars and measure less than 3,000 light-years across. The galactic supergiants contain billions of Suns and are more than 150,000 light years across.

## GALAXY SHAPES

■ **Spiral Galaxy** Spinning spiral galaxies have long, curved arms. Young stars, pink nebulas, and dust are found in the arms.



■ **Barred Spiral** Barred spirals have long, trailing arms and a central bar. The center of the bar is thought to be where stars are born.



■ **Elliptical Galaxy** These galaxies are round and made up of older stars. Many are found in galaxy clusters. Most are thought to hold supermassive black holes.



■ **Irregular Galaxy**

Galaxies with no recognizable shape are irregular. They are small, with lots of young stars and bright nebulas.



◀ **THE WHIRLPOOL GALAXY** This is a huge, well defined spiral galaxy, 31 million light-years away. Its smaller satellite galaxy can be seen. There are thought to be supermassive black holes at the center of most spiral galaxies.



*The Antennae nuclei (yellow) are colliding to form one giant galaxy*

**ANTENNAE GALAXIES** A well-known collision involves the two Antennae galaxies. They are 45 million light-years from Earth and were lit up by bursts of star formation as they collided.

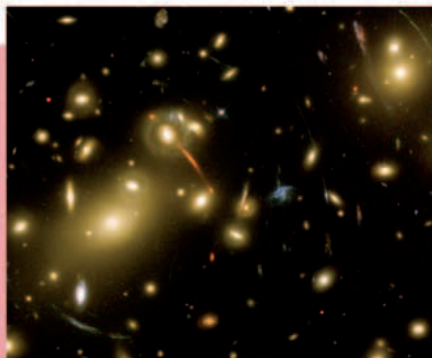
### Colliding galaxies

Most galaxies are separated by vast distances, but sometimes galaxies collide. In fact, the very common elliptical galaxies are thought to have grown through collisions with other galaxies long ago. During collisions, the clouds of gas between the stars are forced together, triggering the birth of new stars. One of the best known examples is the Antennae galaxies.

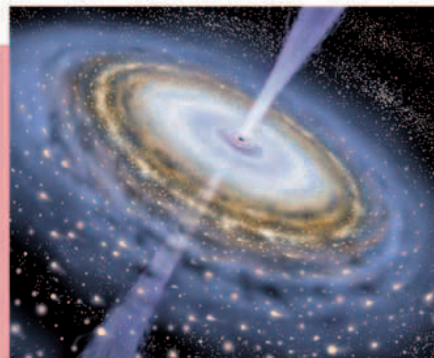
### GALAXY FACTFILE



▲ **SATELLITE GALAXIES** Most large galaxies have smaller, satellite galaxies in orbit around them. The Andromeda galaxy has many satellite galaxies, two are shown in this photo. The Milky Way has several dozen.



▲ **GALAXY CLUSTER** Galaxies form clusters because of their huge gravitational pull. They often pull each other out of shape and may collide.

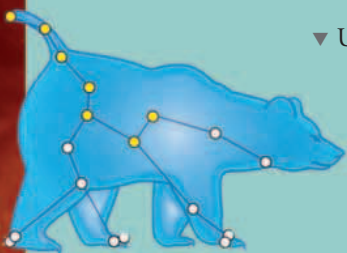


▲ **BLACK HOLE** Most galaxies have supermassive black holes at their centers. Their gravity is so strong that not even light can escape. We can only see the hot gas, dust, and stars getting pulled in.



## TAKE A LOOK

■ **Constellations** Only a few thousand stars can be seen without a telescope. All of these are in our own galaxy. Ancient people saw patterns and shapes (constellations) in them and named them after mythological creatures or people. The most famous are the 12 zodiac constellations. They form a belt across the sky.



▼ **URSA MAJOR** The seven brightest stars, located in the Bear's hindquarters and tail, form the well-known Big Dipper.

# Balls of gas

A star is a huge, glowing ball of hydrogen gas that shines because of nuclear reactions in its core. The hottest stars die within a few million years. Red dwarf stars are the coolest and live the longest.

The small orange dots are stars that are still forming.

There are four young, massive stars at the center of the Orion Nebula.

The clouds are many different colors because they are made up of different gases and dust particles.

**Orion Nebula**  
This galaxy is 15,000 light-years away from Earth.

## STAR BIRTH

■ **Most stars are born** inside giant dust clouds called nebulas. Parts of these clouds collapse and as they shrink, the gas and dust get hotter and forms a star. When nuclear reactions begin in its core, radiation makes the surrounding material glow. Eventually, this is blown away and the star appears.

**GHOST HEAD NEBULA** An extremely hot, newborn star lights up the nearby gas and dust.

◀ The Ghost Head Nebula is a star-forming region in the Large Magellanic Cloud, a satellite galaxy of the Milky Way. The "eyes of the ghost" are two very hot, glowing blobs of gas that are heated by nearby, massive stars.



# The Sun

- **Diameter** 863,746 miles (1,390,000 km)
- **Mass (Earth=1)** 330,000
- **Core temperature** 27,000,032°F (15,000,000°C)
- **Distance from Earth** 93,000,000 miles (150,000,000 km)

The Sun is our nearest star. Without the Sun, the Earth would be frozen and lifeless. The Sun was born in a cloud of gas and dust about 4.6 billion years ago and is now halfway through its life.

**WOW!**

The color of a star is a guide to its surface temperature. The hottest stars are blue or white, stars like the Sun are yellow, and cool stars are orange or red.

*Huge plumes of hot gas sometimes stream away from the Sun. They are called prominences.*

## FACT FILE

- Betelgeuse, a red supergiant, is about 700 times the size of the Sun.
- Neutron stars are only about 12 miles (20 km) across, but so heavy that one teaspoonful would weigh a billion tons.
- Brown dwarfs are stars that weren't hot enough for nuclear reactions to begin.

*Brown dwarf (right) with a nearby orbiting object (red).*



## THE SUN

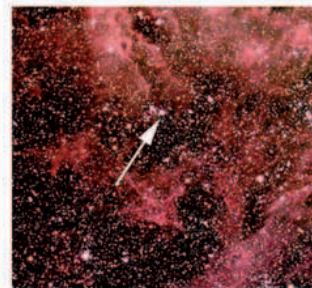
The Sun is a yellow dwarf, a fairly ordinary star made mainly of hydrogen. Hydrogen is changed to helium at its center (the core). When this happens, huge amounts of radiation are released.

## STAR DEATH

- **Planetary nebulas** Small stars expand to become red giants. When they run out of fuel they collapse. Their outer layers are puffed out in rings called planetary nebulas. Each star creates a different shape, such as a cat's eye (below), a butterfly, or a ring. The central star shrinks to a tiny, hot white dwarf.



▲ *The Cat's Eye Nebula is made up of many gas clouds ejected by a dying star.*



Before



After

- **Supernovas** When big stars run out of fuel, they collapse. Their outer layers explode into space in a supernova (right). These can briefly outshine an entire galaxy, but are rare events. The photograph on the left shows the same star ten days before a supernova. Medium-sized stars become neutron stars. Massive stars create black holes.



# The solar system

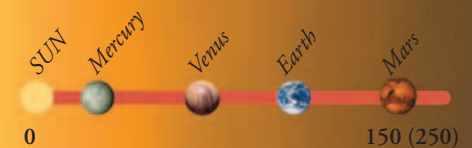
The solar system is our local area of space. As its center is the Sun, our nearest star, which accounts for almost all (99.9 percent) of the solar system's mass. The Sun's gravity keeps the planets in their orbits.

## DISTANCE FROM THE SUN

The red line to the right shows the distance of each planet from the Sun in millions of miles and kilometers. Mercury is closest and Neptune is farthest away. Earth is about 93 million miles (150 million km) from the Sun.



*All of the planets and asteroids go around the Sun in near-circular orbits in the same direction (west to east).*



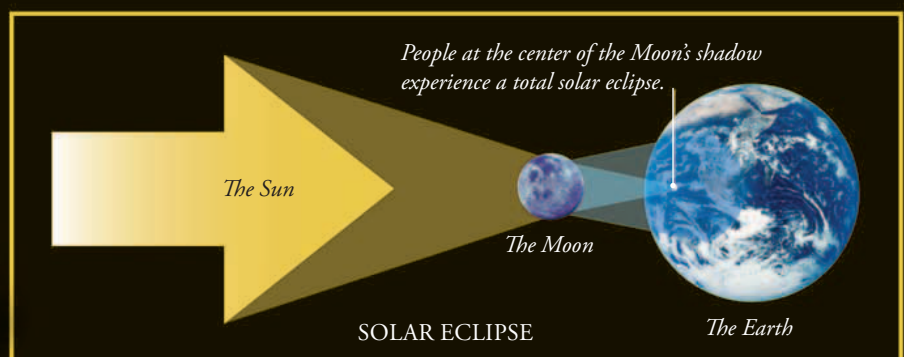
## INNER PLANETS

The four planets nearest the Sun are called the inner planets. They are also known as the rocky planets because they are balls of rock and metal. They are dense and have central cores made of iron.

## LUNAR AND SOLAR ECLIPSES

In any year there can be up to seven solar or lunar eclipses, when light from the Sun or Moon is blocked for a short time. Solar eclipses are more common, but are seen only in a narrow area. Lunar eclipses can be seen anywhere on Earth where the Moon is shining in the sky.

*A "diamond ring effect" appears just before or just after an eclipse of the Sun. Then the Sun's corona (atmosphere) can be seen around the Moon.*

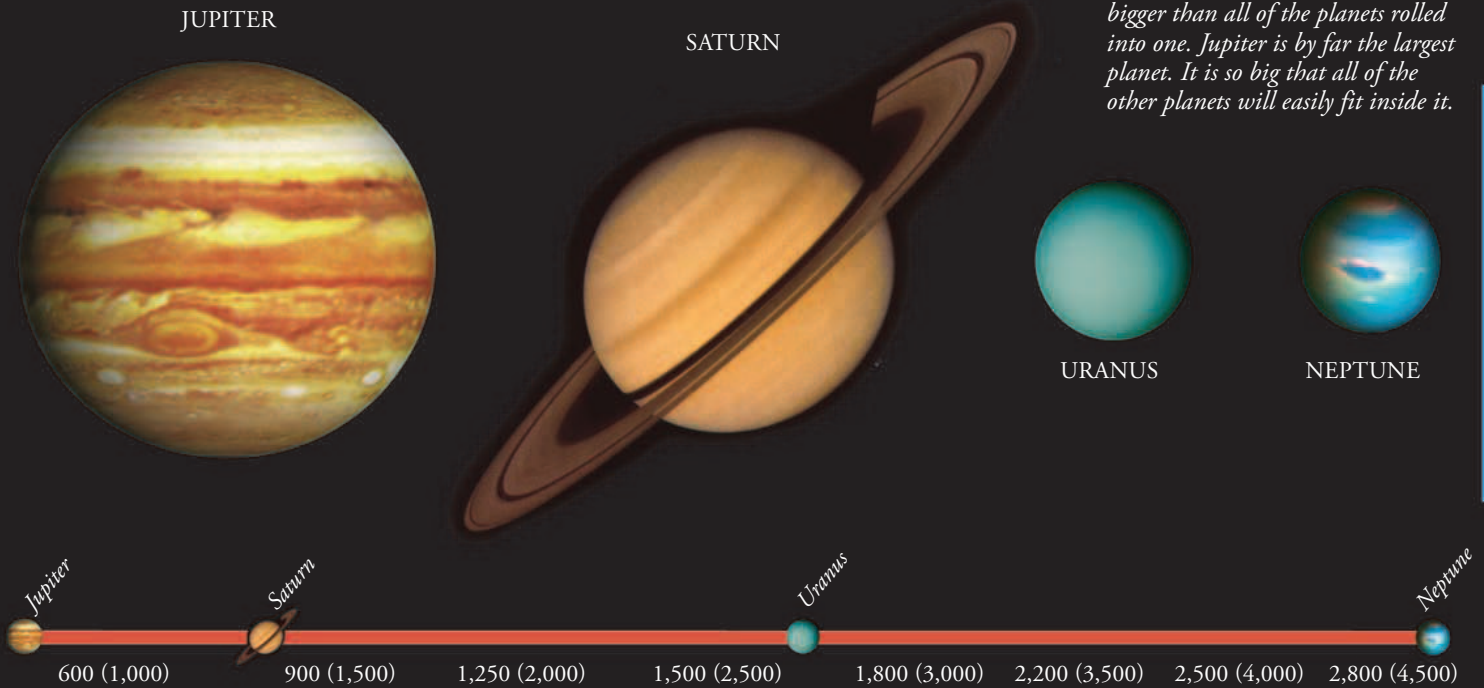


■ A lunar eclipse happens when the Earth passes between the Sun and the Moon, so that the Earth casts a shadow on the Moon.

■ A solar eclipse happens when the Moon passes between the Earth and the Sun, casting a shadow on the Earth. A total eclipse lasts for up to eight minutes.

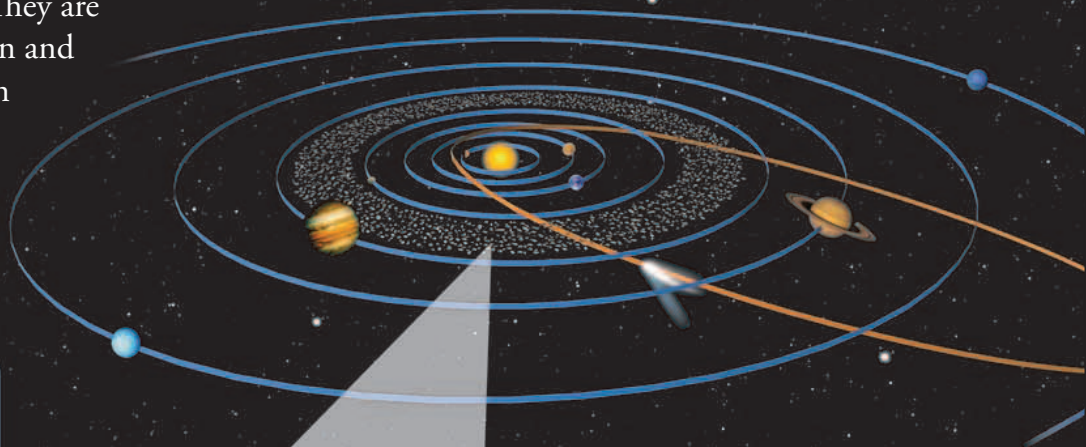


▼ **SCALE OF THE PLANETS**  
*The Sun is thousands of times bigger than all of the planets rolled into one. Jupiter is by far the largest planet. It is so big that all of the other planets will easily fit inside it.*



## OUTER PLANETS

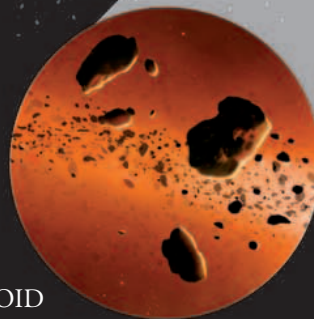
The four planets farthest away from the Sun are called the outer planets. They are huge balls of gas (mainly hydrogen and helium) and liquid and are known as the gas giants. Uranus and Neptune are also known as the ice giants.



### FAST FACTS



- Only six planets were known before telescopes were first used to look at the sky in 1609.
- The planets were born in a huge cloud of gas and dust about 4.5 billion years ago.
- About 4 billion years ago the Sun was 25 percent dimmer than it is today.
- Halley's comet doesn't orbit the Sun in the normal clockwise direction. It travels from beyond Neptune to inside the orbit of Venus.
- Excluding the Sun, Jupiter and Saturn contain 90 percent of the solar system's mass.



#### ▶ ASTEROID BELT

*Between*

*Mars and Jupiter is the asteroid belt.*

*It separates the inner planets from the*

*outer planets. About 15,000 asteroids*

*have been found and named. They are*

*thought to be rocks that never clumped*

*together to form planets.*

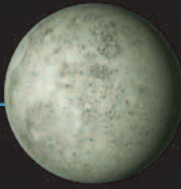
## ORBITING THE SUN

The solar system includes eight planets, five dwarf planets, more than 150 moons, and millions more comets and asteroids. These bodies are all orbiting the Sun.



## Mercury

*Messenger of the Roman gods*



- **Earth days to orbit Sun** 88
- **Discovery date** Unknown (but known since ancient times)
- **Number of moons** None
- **Location** First planet from the Sun

The solar system's smallest planet, and the densest, temperatures on Mercury range from a freezing—279°F (173°C) to a blistering 801°F (427°C). Unlike Earth, Mercury has no atmosphere, so the planet cannot retain heat.

## Venus

*Roman goddess of love*



- **Earth days to orbit Sun** 224.7
- **Discovery date** Unknown (but known since ancient times)
- **Number of moons** 0
- **Location** Second planet from the Sun

Venus is almost the same size as the Earth, but you wouldn't want to visit Venus. Its atmosphere is incredibly dense and the temperature is so high you would be fried to a crisp. The planet is covered in acid clouds that trap heat.

## Uranus

*Greek god of the sky*

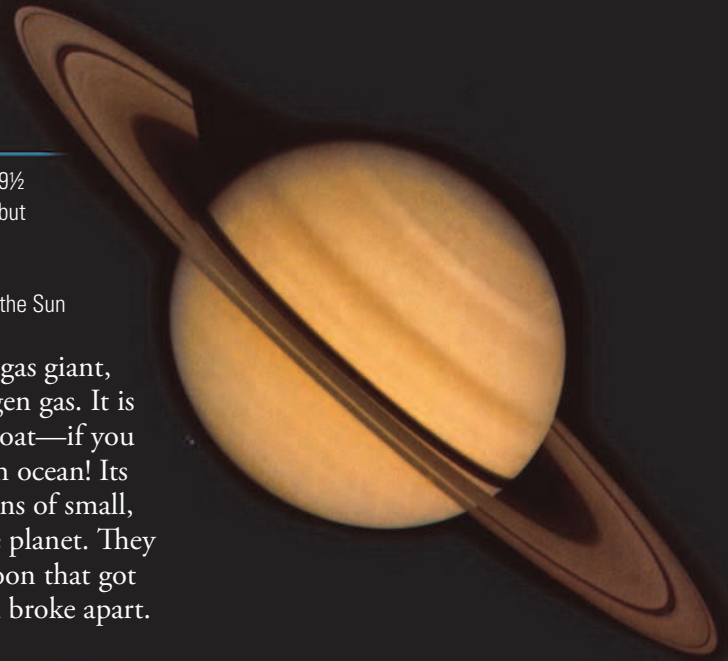


- **Earth years to orbit Sun** just over 84
- **Discovery date** 1781
- **Number of moons** 27
- **Location** Seventh planet from the Sun

Uranus was discovered in 1781 by William Herschel. Much of the planet is thought to be made of water and ice. It has 11 thin, dark rings. The planet spins on its side, like a top that has fallen over. This is probably the result of a huge impact long ago.

## Saturn

*Roman god of agriculture*

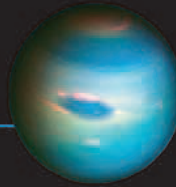


- **Earth years to orbit Sun** 29½
- **Discovery date** Unknown (but known since ancient times)
- **Number of moons** 60
- **Location** Sixth planet from the Sun

Saturn is an enormous gas giant, made mainly of hydrogen gas. It is so light that it would float—if you could find a big enough ocean! Its rings are made of billions of small, icy chunks orbiting the planet. They are the remains of a moon that got too close to Saturn and broke apart.

## Neptune

*Roman god of the sea*

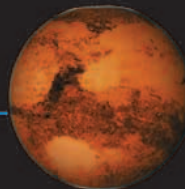


- **Earth years to orbit Sun** 165
- **Discovery date** 1846
- **Number of moons** 13
- **Location** Eighth planet from the Sun

This is an icy planet. That's because it is 30 times farther away from the Sun than Earth. A day on Neptune lasts 16 hours and 7 minutes. Neptune has huge storms and very strong winds. It also has six dark, thin rings.

## Mars

*Roman god of war*



- **Earth days to orbit Sun** 687
- **Discovery date** Unknown (but known since ancient times)
- **Number of moons** 2
- **Location** Fourth planet from the Sun

Mars is one of the closest planets to us in space. It is barren and mainly covered with dust and rocks. Two ice caps cover the poles. It is about half the size of the Earth, but has no flowing water, which means there is no life.

## Jupiter

*King of the Roman gods*



- **Earth years to orbit Sun** 12
- **Discovery date** Unknown (but known since ancient times)
- **Number of moons** 63
- **Location** Fifth planet from the Sun

The solar system's largest planet, Jupiter is a gas giant made mainly of hydrogen. It has many storms in its deep, cloudy atmosphere. The largest of these, which has been blowing for at least 300 years, is called the Great Red Spot. Jupiter has more moons than any other planet.

## Earth



- **Earth days to orbit Sun** 365.2
- **Number of moons** 1
- **Location** Third planet from the Sun

Earth is the only planet known to support life. It has the right temperature for life because it's neither too close to the Sun, nor too far from it. Earth is the only planet with oceans on its surface. It is also the only planet with lots of oxygen—the gas that keeps us alive.



# Moon

*Luna*

- **Days to orbit Earth** 27.3
- **Discovery date** Unknown (but known in ancient times)
- **Location** Only moon of the Earth

The Moon orbits Earth at an average distance of 238,855 miles (384,400 km)—a journey of three days by spacecraft. It was born when a huge Mars-sized object crashed into the young Earth. The dark patches on its surface that make up the face of “the man in the Moon” are old seas of lava. The Moon has no atmosphere.



## THE OCEAN PLANET

Earth is the only planet with oceans of water on its surface. This water turns to gas, then forms clouds and rain (or snow). It is also the only planet we know with lots of oxygen—the gas that keeps us alive. Its powerful magnetic field shields Earth from harmful particles and radiation from the Sun.

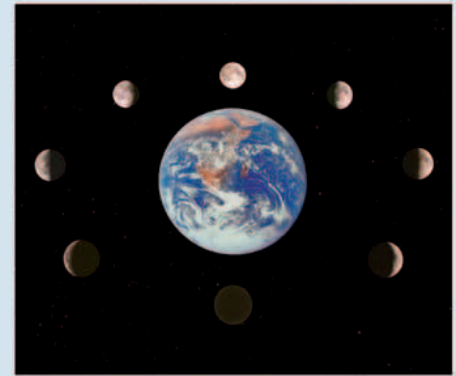
▶ **LIFE ON EARTH** *Life is thought to have existed on Earth for almost four billion years.*

### FAST FACTS

- The planets of our solar system orbit the Sun in nearly perfect circles.
- Our nearest neighbor, Venus, is only 23½ million miles (38 million km) away during close approaches.
- Use this simple sentence to remember the order of the planets: **My Very Educated Mother Just Served Us Noodles** (My = Mercury, Mother = Mars).
- Even today, comets and small asteroids crash into the planets (including Earth). One impact 65 million years may have wiped out the dinosaurs.

## TAKE A LOOK: PHASES OF THE MOON

As the Moon orbits Earth, it seems to change shape night after night. We say it goes through phases. This is because we see different amounts of the Moon’s sunlit side. At new Moon it is dark and cannot be seen (except during a solar eclipse). At full Moon the entire Earth-facing side is lit up by the Sun (👁️ p. 31).



▶ **MOONS** *The period from full Moon to full Moon lasts 29½ days.*

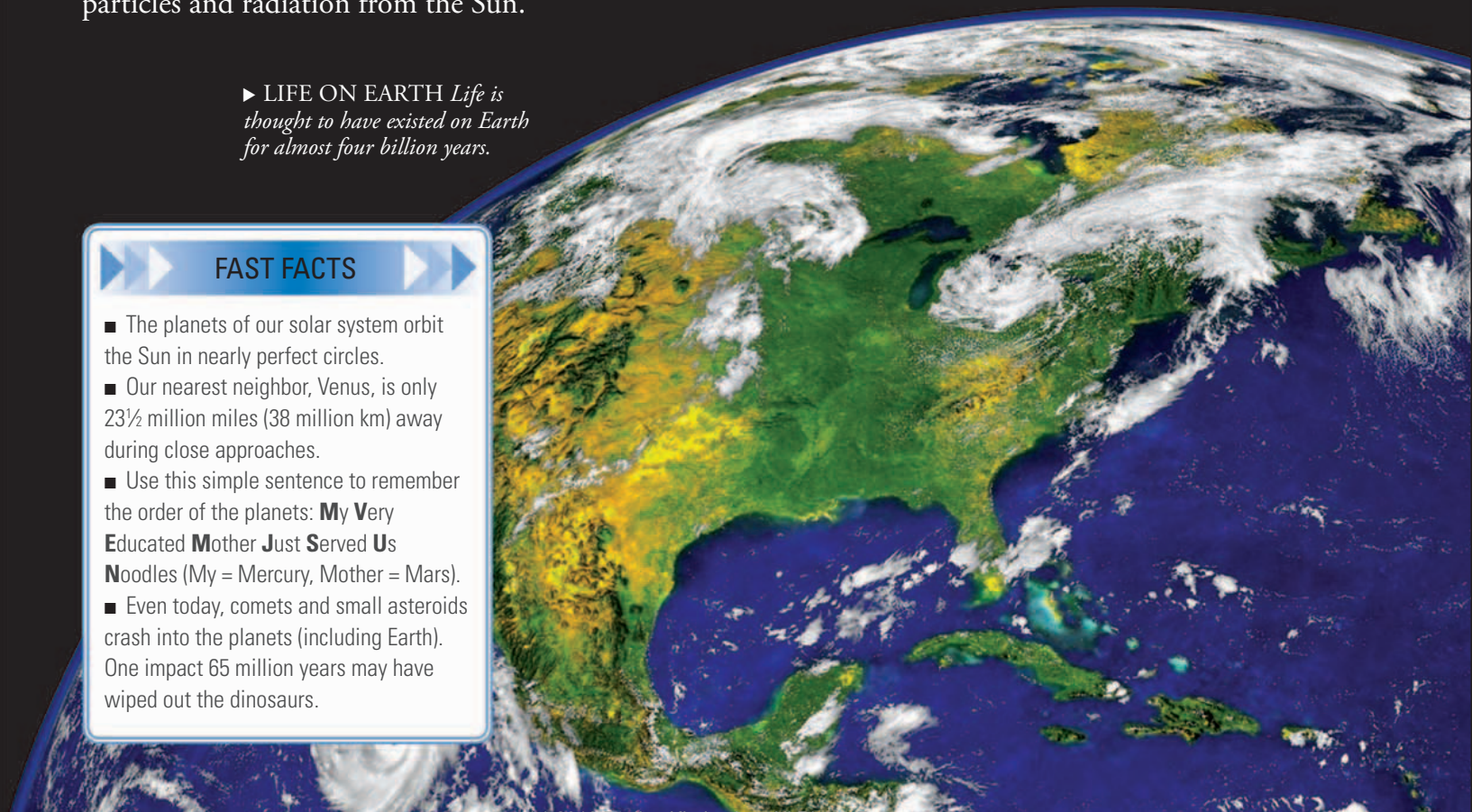
◀ **HIDDEN FAR SIDE** *The Moon always keeps the same side pointing toward Earth. We never see the “far side.”*

## WOW!

Earth and Mars have had many ice ages in the past. When they get colder, ice sheets spread out from the poles and cover large areas.

Most of the Earth may have been covered in ice 600 million years ago.

Ice ages happen because of changes in the orbits and tilt of the planets.

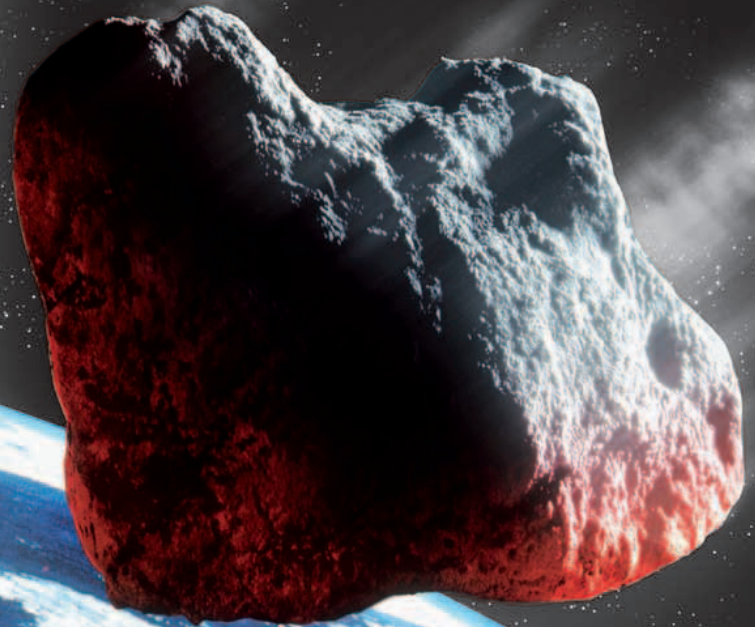




# Flying rocks

There are billions of rocks in the Milky Way that never became big enough to be planets. They orbit the Sun and sometimes crash into each other and the planets. They can create spectacular light shows in the sky or even devastate whole planets.

**ASTEROIDS** are small, rocky bodies that orbit the Sun. Most of them are found between the orbits of Mars and Jupiter. They are leftovers from the birth of the planets 4.5 billion years ago. The main asteroid belt contains tens of thousands of asteroids. The first one, Ceres, was discovered in 1801.



## Pluto

*The Roman god of the underworld*

- **Diameter** 1,441 miles (2,320 km)
- **Mass (Earth=1)** 0.002
- **Year to orbit Sun** 248
- **Number of moons** 3

Pluto was discovered in 1930. In 2006, astronomers decided it should be classed as a dwarf planet. It is smaller and lighter than the Moon and its egg-shaped orbit means that it sometimes comes closer to the Sun than Neptune. Pluto is very cold because it is so far away from the Sun.



### DWARF PLANETS

*Other than Pluto, there are four dwarf planets—Haumea, Eris, Makemake, and Ceres. Ceres is the only asteroid big enough to be classed as a dwarf planet. The other dwarf planets are much like Pluto and are found in the outer solar system beyond the orbit of Neptune.*

## WOW!

Most meteorites are too small to cause much damage. However, 65 million years ago, a 6 mile- (10 km-) wide asteroid hit the Earth, causing massive earthquakes and tidal waves. A cloud of dust from the impact entered the atmosphere and blocked sunlight, causing plants and animals to die. This impact may have ended the age of the dinosaurs.



► **COMETS** orbit the Sun in the outer solar system and sometimes appear in our skies. They have two tails—of gas and dust—and a solid nucleus made of ice. The Hale-Bopp comet passed near our Earth in 1997. It was one of the brightest comets of the 20th century.



**Meteor showers** occur at the same time each year, when the Earth passes through trails of dust left by passing comets. Very rarely, a shower may produce thousands of shooting stars that light up the sky.

## METEORITES

Meteorites are small chunks of rock that have come from space and landed on the Earth's surface. Most of them are pieces that have broken off asteroids. A few have come from the Moon and Mars.

### ► METEOR CRATER

*One of the youngest and best-preserved craters on Earth is in Arizona. It is 50,000 years old and 600 ft (180 m) deep.*



## TAKE A LOOK: METEORS

Look up at the sky on a cloudless night and you will eventually see a meteor, or “shooting star.” Meteors are particles of dust and rock that burn up as they enter the Earth's atmosphere.



■ It's strange to think that the Willamette meteorite (above), now found in a museum, was once a brilliant fireball shooting toward the Earth. It's made of iron and nickel.

The crater is 4,000 ft (1,200 m) wide



# Eye spy space

People have been staring at the heavens since prehistoric times. They measured the positions of the stars and watched the movement of the Sun, Moon, and planets across the sky. But there was a limit to what could be learned with the naked eye.

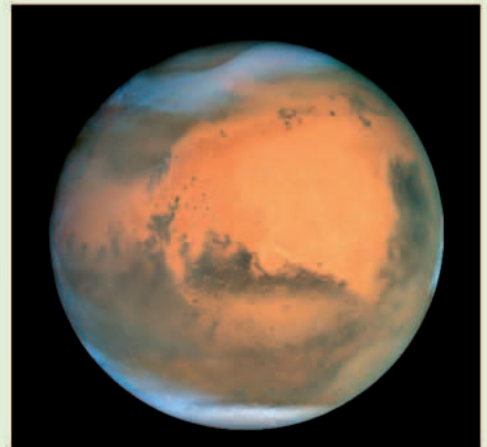
**LICK TELESCOPE** *The James Lick Telescope is an antique refracting telescope built in 1888. It is the third largest example of this type of telescope in the world. It is in California and is 4,209 ft (1,283 m) above sea level.*

## WOW!

In order to avoid becoming ill with altitude sickness, people visiting mountaintop observatories, such as Keck I and II, have to stop and wait halfway up the mountain. This allows their bodies to adapt to the decrease in oxygen in the air.

### TAKE A LOOK

Optical telescopes can obtain images of far-away planets and stars. Other telescopes study the universe by capturing radio waves, X-rays, and other types of radiation.



▲ **MARS FROM HUBBLE** *This picture of Mars was taken with the Hubble Space Telescope. It shows the southern polar cap, the orange deserts, and sheets of ice cloud.*



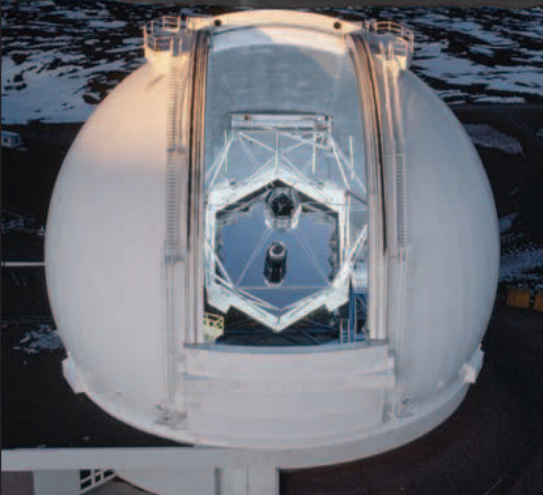
## Keck I and II

*Largest optical telescopes today*

- **Overall height** 81 ft (24.6 m)
- **Total moving weight** 300 tons (270 metric tons)
- **Total weight of glass** 16 tons (14.6 metric tons)
- **Location** 13,800 ft (4,200 m) above sea level on Mauna Kea, Hawaii

The largest optical telescopes today are the identical Keck I and II, each with 33 ft- (10 m-) wide mirrors. They are on an extinct volcano in Hawaii. Their telescopes are linked so that the light they collect can be combined. Giant air conditioners run constantly during the day, keeping the dome temperatures at or below freezing.

*Each main mirror is made of 36 segments that act like a single piece of glass.*



## James Webb

*Largest space telescope*

- **Length** 72 ft (22 m)
- **Weight** 14,300 lb (6,500 kg)
- **Mission length** 5–10 years
- **Location** 1 million miles (1.5 million km) from Earth

In 2013, the James Webb Space Telescope will replace the Hubble Space Telescope. It will have a 21 ft (6.5 m) mirror (nearly three times bigger than Hubble's).



SPACE

## Chandra

*Most powerful X-ray observatory*

- **Length** 45½ ft (13.8 m)
- **Weight** 10,560 lb (4,800 kg)
- **Mission length** 10 years
- **Location** Earth orbit

Today, large space observatories, like Chandra, are used to study very hot X-ray objects such as supernovas, white dwarfs, and active galaxies. X-rays are captured by four pairs of cylindrical mirrors.



## Hubble space observatory

*Famous NASA-ESA observatory*

- **Height** 43¾ ft (13.3 m)
- **Weight** 23,855 lb (10,843 kg)
- **Mission length** 23 years
- **Location** Earth orbit

Launched in 1990, the world's most famous space telescope has a 7½ ft (2.4 m) mirror. It is named after American astronomer Edwin Hubble, who showed that the universe is expanding.



## Very Large Array

*27-dish radio telescope*

- **Size** 27 dishes, each 82 ft (25 m) across
- **Length of each railroad arm** 13 miles (21 km)
- **Location** Socorro, New Mexico

The Very Large Array is currently the world's largest radio telescope array, consisting of 27 dish antennae. The dishes can be moved along the arms of a Y-shaped railroad network.



## Allen Telescope Array

*350-dish radio telescope*

- **Size** 350 dishes, each 20 ft (6.1 m) across
- **Location** Hat Creek, California

Currently under construction the array is planned to contain 350 dishes inside a 2/3 mile- (1 km-) wide circle. They will be linked and act as a single dish to study the distant universe and search for alien life.

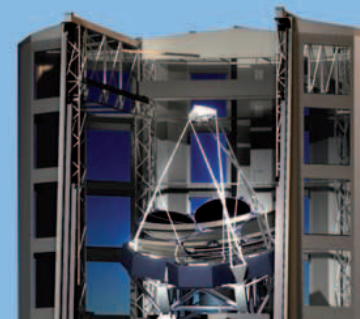


## Giant Magellan

*Seven mirror optical giant*

- **Height** Seven 27½ ft (8.4 m) mirrors
- **Total moving weight** more than 1,100 tons (more than 1,000 metric tons)
- **Location** Cerro Las Campanas, Chile

Due to be completed in 2017, the Giant Magellan will produce images ten times sharper than the Hubble Space Telescope.





# The Apollo program

In the early 1960s, Russia was ahead in the space race, so President Kennedy announced that American astronauts would land on the Moon before 1970. In July 1969, after spending 25 billion dollars on the *Apollo* program, they did.

## GETTING THERE



■ The astronauts' journey to the Moon would not have been possible without the *Saturn V*, the most powerful rocket ever built. The huge, three stage rocket towered 360 ft (110 m) above the Florida launch pad. After the first two stages ran out of fuel, they were released and the third stage was used to boost the *Apollo* spacecraft and its crew toward the Moon.



**First man on the Moon** *Apollo 11* was the first manned mission to land on the Moon. On July 20, 1969, the lunar module *Eagle* landed and Neil Armstrong made the first lunar footprint.



## APOLLO TIMELINE

1966

**February 26**

First unmanned test flight of *Saturn 1B* rocket. It eventually carried the first manned *Apollo* test flight to orbit the Earth.

1967

**January 27**

Gus Grissom, Edward White, and Roger Chaffee were killed on the launch pad by a fire in their *Apollo* spacecraft during a launch test.

1968

**October 11**

First manned *Apollo* flight tests the Command Module in Earth orbit.

**December 21**

First manned flight around the Moon.

1969

**July 20**

*Apollo 11* makes the first manned landing on the Moon.



## APOLLO SPACECRAFT

For the three-day trip between Earth and the Moon, the *Apollo* crew spent most of their time in the cone-shaped Command Module (CM). The crew also returned to Earth in the Command Module and landed by parachuting into the ocean.

### ▼ COMMAND MODULE

*One astronaut stayed in the CM in orbit around the Moon. The others went down to the Moon's surface.*



◀ LUNAR MODULE *The Moon lander was officially called the lunar module. The crew lived in the upper of the two sections. It was this section that blasted off from the Moon and carried them back to the CM.*

## TAKE A LOOK

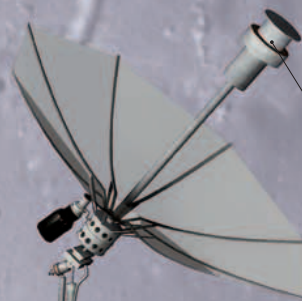


Scientists wanted to learn more about the Moon, so astronauts collected lots of soil and rock samples.

► *Bending in spacesuits wasn't easy, so tools were designed to pick things up. Altogether, 838 lb (380 kg) of rocks were brought to Earth and stored in a special room.*

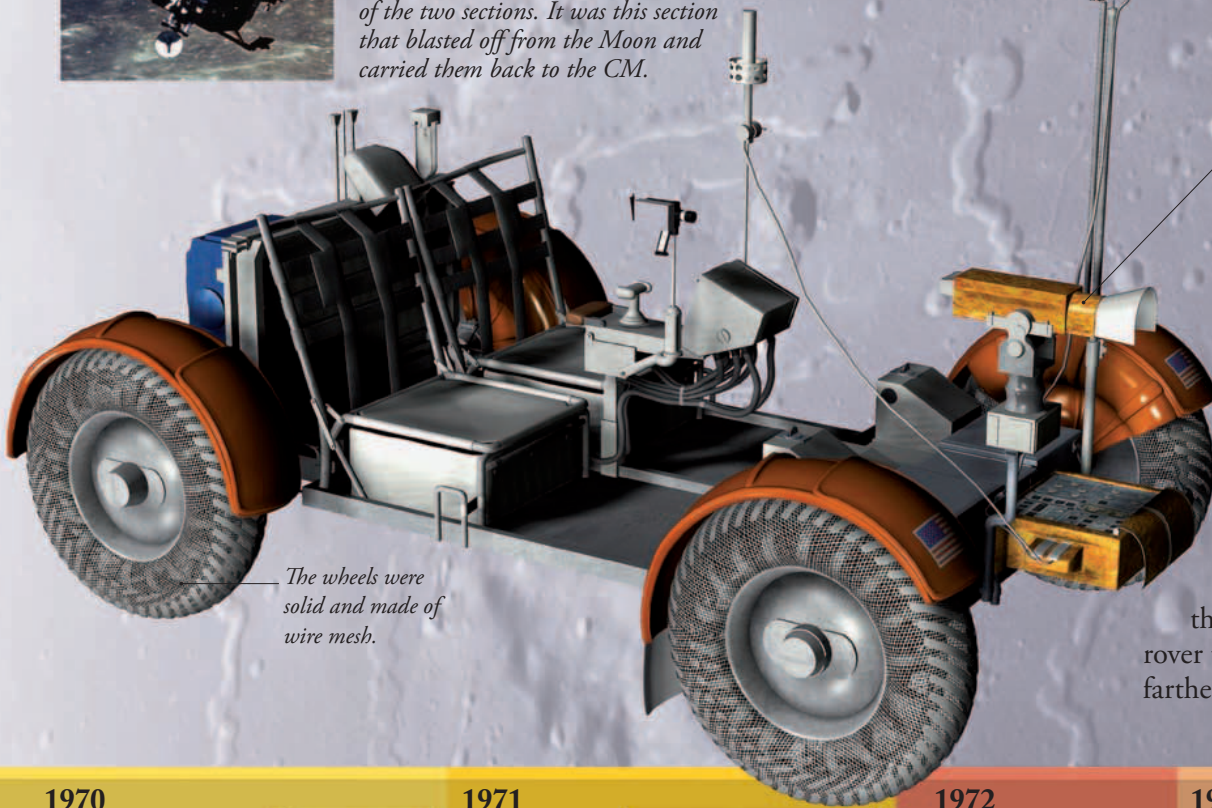


SPACE



*Dish antenna for communications with Earth.*

*A camera took pictures and sent them back to Earth.*



*The wheels were solid and made of wire mesh.*

**The Moon buggy**  
Walking and carrying samples was hard work, even in the Moon's low gravity (everything weighs one-sixth of what it does on the Earth).

So NASA gave the last three *Apollo* crews a lunar rover to drive. Crews traveled farther and could carry more.

1970

**April 13**

An oxygen tank exploded on *Apollo 13*, canceling its Moon landing.



1971

**July 26**

Launch of *Apollo 15*, the first mission with a rover.



1972

**December 19**

Splashdown of *Apollo 17*, the last manned mission to the Moon.

1975

**July 17**

*Apollo-Soyuz* docking: first joint US-Russian manned mission.

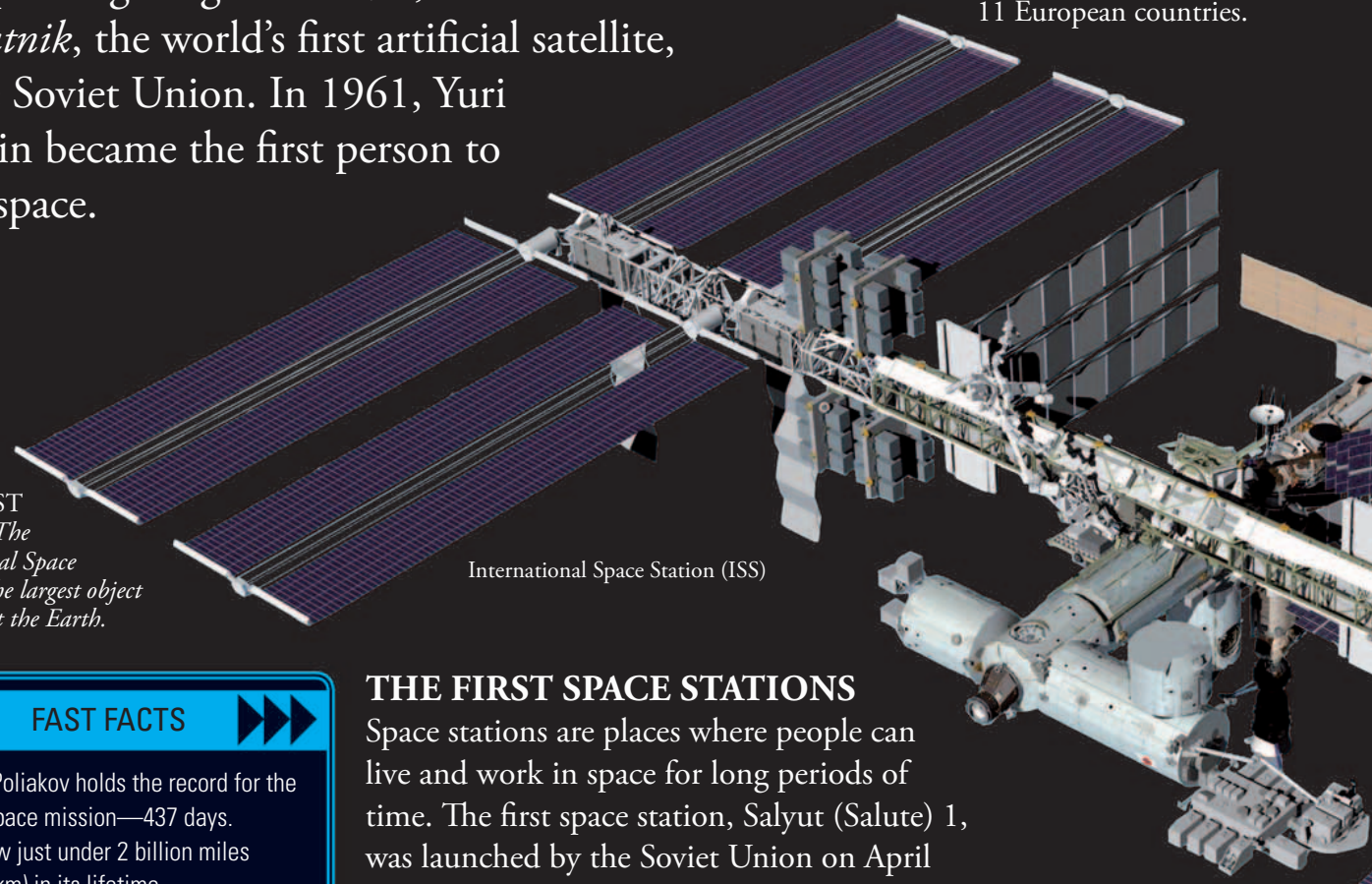




# Exploring *space*

The Space Age began in 1957, with the launch of *Sputnik*, the world's first artificial satellite, by the Soviet Union. In 1961, Yuri Gagarin became the first person to fly in space.

**The International Space Station** is the most expensive and ambitious space project ever flown. The 500 ton (450 metric ton), station is being built in Earth orbit by the US, Russia, Japan, Canada, and 11 European countries.



International Space Station (ISS)

▶ **LARGEST OBJECT** *The International Space Station is the largest object ever to orbit the Earth.*

## FAST FACTS

- Valeri Poliakov holds the record for the longest space mission—437 days.
- Mir flew just under 2 billion miles (3 billion km) in its lifetime.
- Mir space station was home to 111 people (1986–2001).
- The shuttle *Challenger* blew up in 1986, 71 seconds after launch.
- The shuttle *Columbia* broke apart during its return to Earth in 2003.
- About 160 space walks are required to complete the International Space Station.
- More than 90 percent of the world's population can see the ISS when it flies overhead.
- The ISS orbits Earth every 90 minutes.

## THE FIRST SPACE STATIONS

Space stations are places where people can live and work in space for long periods of time. The first space station, Salyut (Salute) 1, was launched by the Soviet Union on April 19, 1971. Six more *Salyuts* were launched until 1986—two of them mainly for taking spy photographs.



▶ **SALYUT 7 SPACE STATION** *The 22 ton (20 metric ton) Salyut 7 space station was launched in 1982 and burned up during reentry in 1991.*

**FOOTBALL FIELD** ▶ *When it is finished in 2010, the ISS will be about the size of a football field.*

## TIMELINE OF SPACE EXPLORATION

### 1950s

**1957**  
First man-made satellite, *Sputnik*, in space.

**1959**  
First pictures of the far side of the Moon (*Luna 3*).

### 1960s

**1961**  
First human in space, Yuri Gagarin.



**1963**  
First woman in space, Valentina Tereshkova.

**1965**  
Alexei Leonov makes first space walk.

**1969**  
First man to walk on the Moon, Neil Armstrong.



**Space shuttle** In 1981, a new space age began when the first reusable spacecraft blasted off from Cape Canaveral, Florida. Five US space shuttle orbiters have been built. They come back to Earth like giant gliders.

▼ **SPACE SHUTTLE LANDING**  
*The shuttle lands on a runway at a speed of 215 mph (345 km/h). If it misses the runway it can't go around and try again. A tail parachute helps to slow it down.*

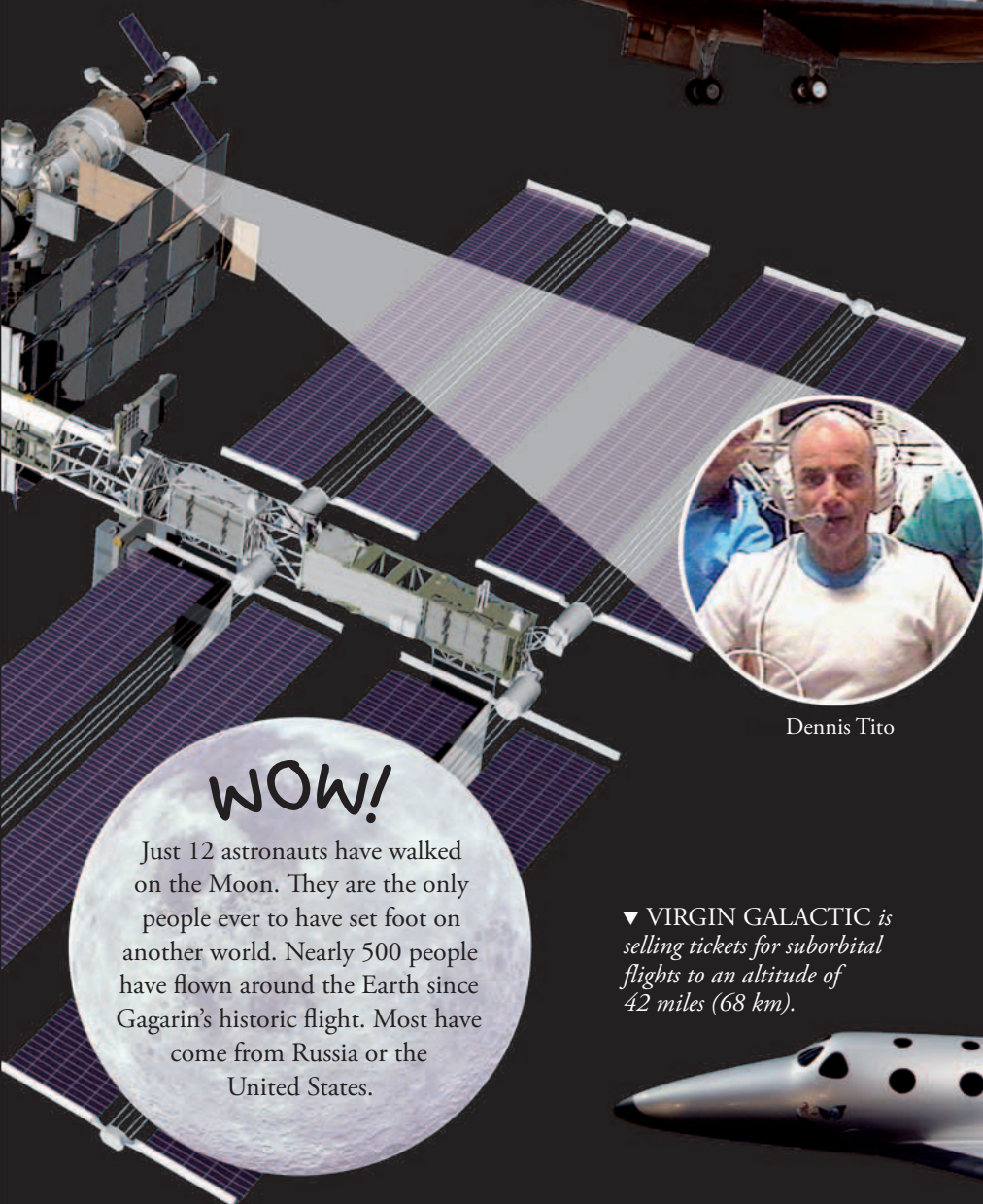


**BACK TO THE MOON**

■ The United States, Russia, Europe, and Japan are planning to send people back to the Moon by 2020. The US is developing the Ares I and V rockets. Ares I will carry a crewed spacecraft called Orion, which will carry six people to the International Space Station and eventually on to the Moon.



▲ **THE SPACECRAFT ORION** will dock with the International Space Station.



Dennis Tito

**Space tourism** Almost all of the astronaut and cosmonaut flights have been funded by tax payers. However, space tourism is becoming increasingly popular. The first real space tourist was millionaire businessman Dennis Tito, who paid \$20 million for a week on board the ISS.

**WOW!**

Just 12 astronauts have walked on the Moon. They are the only people ever to have set foot on another world. Nearly 500 people have flown around the Earth since Gagarin's historic flight. Most have come from Russia or the United States.

▼ **VIRGIN GALACTIC** is selling tickets for suborbital flights to an altitude of 42 miles (68 km).



**1970s**

1973  
 Skylab launch—the first US space station.



1977 *Voyager* 2, then 1 are launched to Jupiter, Saturn, and beyond.

**1980s**

1986  
 First section of *Mir* space station launched.

**1990s**

1998  
 First part of the ISS launched.

**2000s**

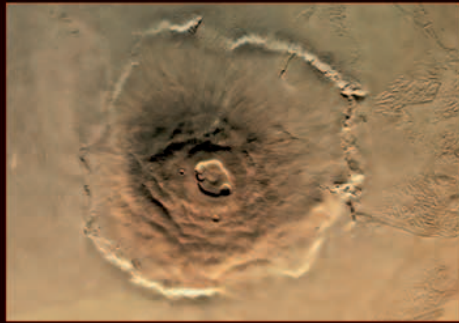
2004  
*Cassini-Huygens* in orbit around Saturn.





# The red planet

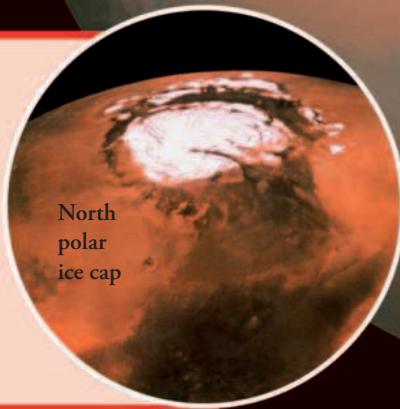
Aside from Earth, Mars is the most suitable planet for humans to live on. It looks red because iron minerals in its surface rocks have rusted. In the past, it was much more like Earth than it is today.



**Volcanoes** Mars has the largest volcanoes in the solar system. The most impressive is Olympus Mons, which is 375 miles (600 km) across and more than 16 miles (26 km) high. The volcano hasn't erupted for millions of years.

## POLAR ICE CAPS

■ There are ice caps at both Martian poles, but they are much smaller than the Earth's. Each pole is different. The northern sheet is about 2 miles (3 km) thick and mainly water ice. The southern polar cap is colder but thicker, and made of water ice with a coating of carbon dioxide ice. The polar caps melt and shrink in summer, then grow in winter when the temperature drops.



North polar ice cap

## GIANT CANYONS

The Valles Marineris are more than 2,500 miles (4,000 km) long—10 times the length of the Grand Canyon—and extend a fifth of the way around Mars. The canyon is about 5 miles (7 km) deep and more than 375 miles (600 km) wide in the center.

These dark circles are volcanoes.

VALLES MARINERIS  
The canyon system was discovered by the Mariner 9 orbiter (after which it was named).

## TIMELINE OF MARS EXPLORATION

### 1960s

1960

*Korabl 4* (USSR) did not reach Earth orbit.

1962

*Mars 1* (USSR) lost contact on way to Mars.

1964

*Mariner 4* (US) the first success returned 21 images.

1969

*Mariner 7* (US) was a success and returned 126 images.

### 1970s

1971

*Mariner 9* (US) the first successful Mars orbiter.

1973

*Mars 5* (USSR) Orbiter got 22 days of data.

1976

*Viking 1* (US) made the first successful landing on Mars.





## WHERE IS THE WATER?

Today, Mars is very cold and the air is too thin for liquid water to exist on the surface. However, huge, winding channels suggest that large rivers raged over the surface long ago.

The water was probably released in sudden floods, possibly when underground ice melted. These river channels have been dry for billions of years.

Northern plains

Southern highlands

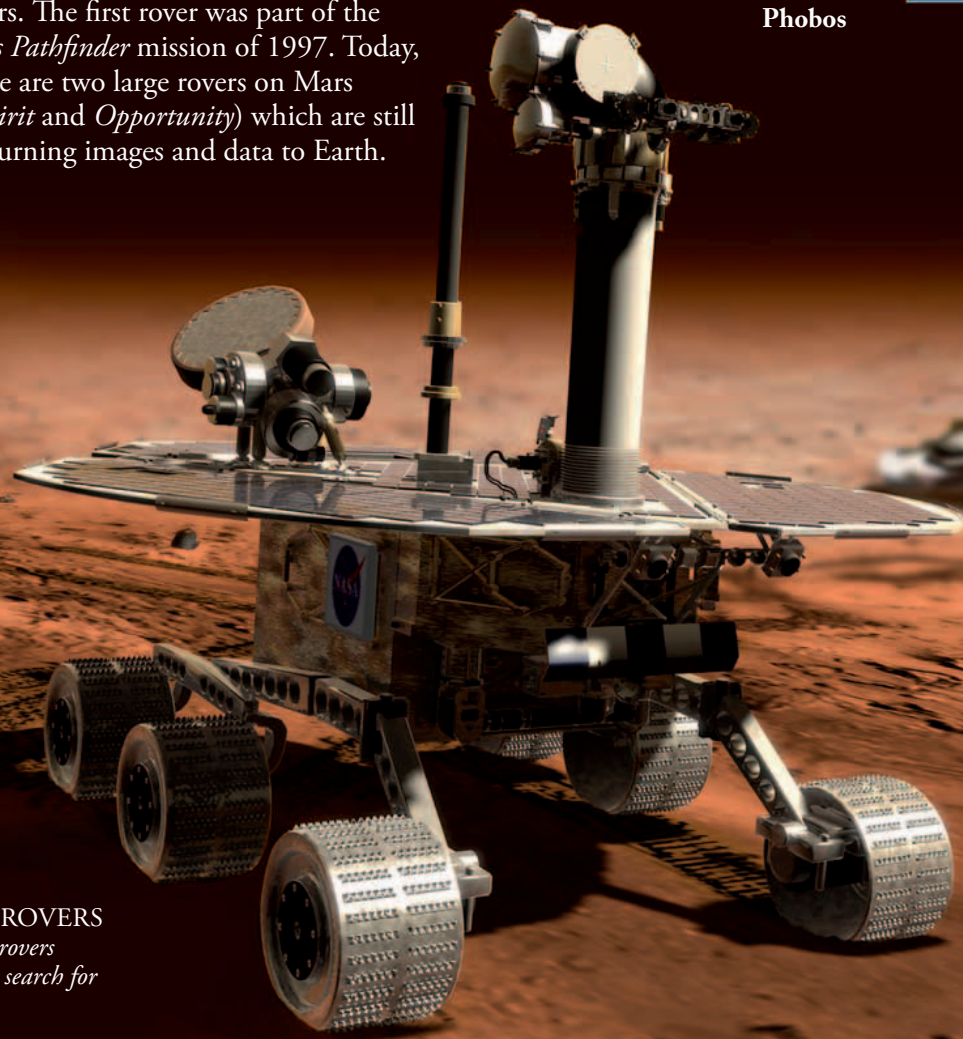
**Mars Explorers** Many robotic spacecraft have been sent to Mars but failed. The successful *Viking* missions in the 1970s included two orbiters and two landers. The first rover was part of the *Mars Pathfinder* mission of 1997. Today, there are two large rovers on Mars (*Spirit* and *Opportunity*) which are still returning images and data to Earth.

WOW!

Mars has two small moons, Phobos and Deimos. They are thought to be asteroids that were captured by Mars long ago. Phobos is no more than 17 miles (27 km) across with large craters on its surface. Deimos is just 7 miles (12 km) across and has a smoother surface.



Phobos



### SPiRiT AND OPPORTUNITY ROVERS

*Two American automated (robotic) rovers landed on Mars in January 2004 to search for evidence of water.*

#### 1980s

##### 1988-89

*Phobos 1* and 2 (USSR) were both lost on route to Mars.



##### 1997

*Mars Pathfinder* (US) delivers first successful rover to Mars.

#### 1990s

##### 1998

*Nozomi* Japan's first Mars explorer failed with fuel problems.

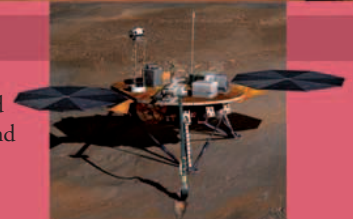
#### 2000s

##### 2003

Europe's *Mars Express* orbiter began taking detailed pictures of Mars.

##### 2008

*Phoenix* (US) landed in Martian Arctic and operated for over 5 months (before its batteries went flat).





# EARTH



- The Earth formed from the gas and dust of a nebula 4.5 billion years ago.
- Earth's inner core is as hot as the surface of the Sun.
- It spins on its axis at about 1,000 mph (1,600 km/h).
- Seventy percent of Earth's surface is covered in water. Most of this is salt water.
- At the moment, Earth is the only planet in the universe known to support life.



How does water shape a coastline?

*Find out on page 45*

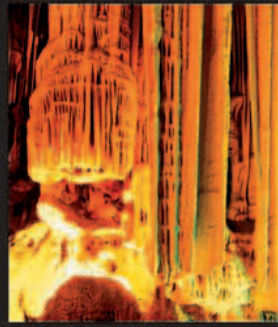


How hard is fluorite?

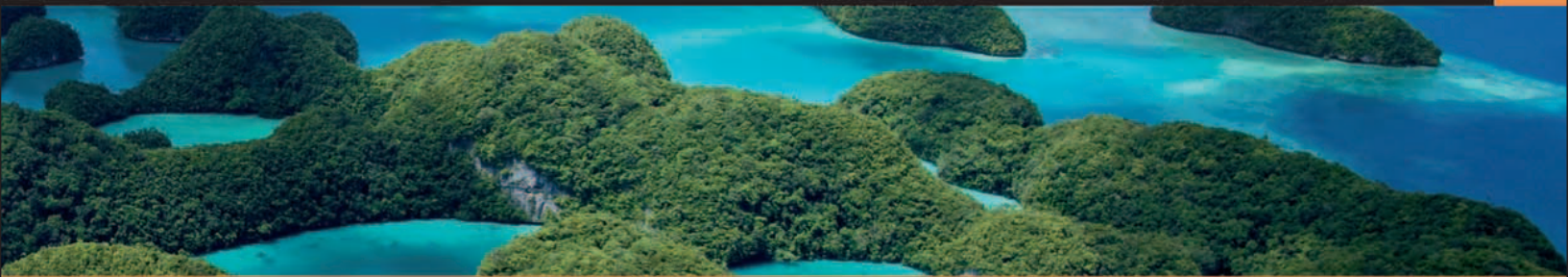
*Find out on page 41*









*Definition:* **Earth** is the planet on which we live. Unlike other planets in our solar system, it is covered with liquid water, which makes it look blue.



- Winds traveling around the Earth can be faster than 200 mph (320 k/ph).
- The highest tsunami on record was 1,720 feet (525 meters) tall.
- A manned submersible has reached an ocean depth of about 7 miles (11 km).
- Stromboli volcano (off the coast of Sicily) has erupted continuously for 2,000 years.
- Earth is surrounded by a thick atmosphere, largely composed of the gas nitrogen.



 How can wind create huge rock sculptures?  
*Find out on page 46*

 What causes Earth's seasons to change?  
*Find out on page 53*

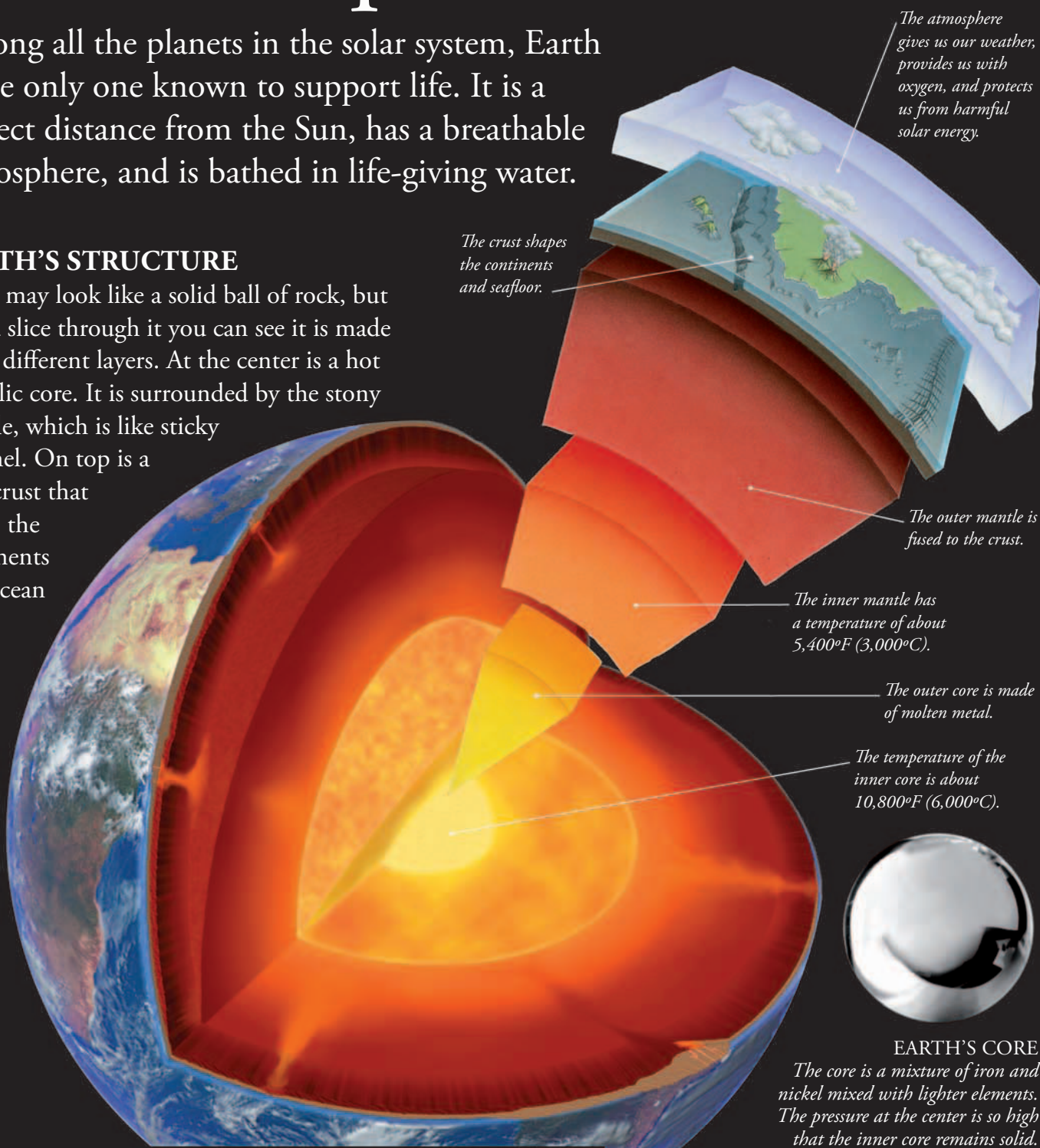


# Our unique world

Among all the planets in the solar system, Earth is the only one known to support life. It is a perfect distance from the Sun, has a breathable atmosphere, and is bathed in life-giving water.

## EARTH'S STRUCTURE

Earth may look like a solid ball of rock, but if you slice through it you can see it is made up of different layers. At the center is a hot metallic core. It is surrounded by the stony mantle, which is like sticky caramel. On top is a thin crust that forms the continents and ocean floor.



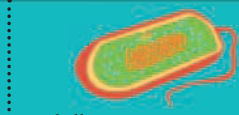
## TIMELINE OF LIFE ON EARTH

### EARLY EARTH

4.5 billion years ago: Earth forms into a red-hot ball of liquid rock.

4.2 billion years ago: Earth develops a crust, and oceans form.

### FIRST LIFE

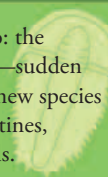


3.5 billion years ago: first living cells.

630 million years ago: complex (multicellular) animals evolve.

### EXPLOSION OF LIFE

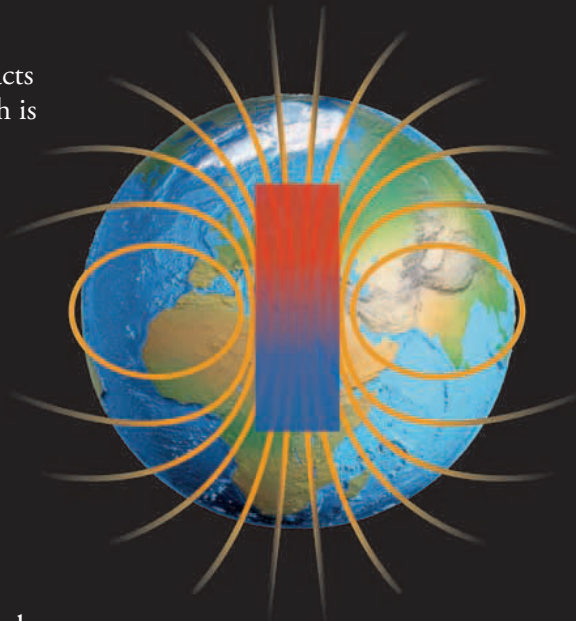
540 million years ago: the Cambrian explosion—sudden appearance of many new species with teeth, feet, intestines, spines, and hard shells.



416 million years ago: first land animals appear.  
500 million years ago: Earth's atmosphere becomes breathable.



**Magnetic field** Our Earth acts like a huge bar magnet, which is why it has north and south poles. The magnetic field is thought to be produced by movement in the liquid outer core. The molten metal carries an electrical charge, which generates an electromagnetic field as it swirls around.



TAKE A PICTURE

Auroras are created when high-energy particles are drawn in at the poles by the magnetic field. This energizes atoms in the atmosphere, which show as curtains of light.

**DAY AND NIGHT**

Our planet doesn't stand still. Every 24 hours it revolves once around its axis, so that half the planet is in sunlight and the other half is in darkness. If it didn't rotate, one side would have permanent day and the other, permanent night.



**Phases of the moon** If you look at the night sky you will see that the appearance of the Moon changes over the course of a month. As the Moon orbits the Earth, the angle between it and the Sun shifts, so that the amount of the Moon's face that is lit by the Sun changes. It is difficult to see a new Moon since the light is shining on the side we cannot see. A slender crescent then appears and gradually increases (waxes) until the full face is lit. It then starts to decrease (wane) back into darkness.

*We only ever see the same face of the Moon because for every orbit it makes around Earth it spins once on its axis.*

**PANGAEA**

225 million years ago: all land joined into one continent, Pangaea.

**AGE OF THE DINOSAURS**

145 million years ago: the modern continents begin to take shape.

225 million years ago: the age of the dinosaurs begins.



65 million years ago: mass extinction of species, including the dinosaurs.

**HUMANKIND**

250,000 years ago, modern humans appeared.



Today



# Dynamic planet

Earth's surface is constantly changing. The rocks it is made from have been recycled many times. Even though we rarely feel it moving, the signs that our planet is active are all around us.

**WOW!**

Earth has had a solid outer skin for at least 4.4 billion years. Even though the rocks that currently make up the surface are much younger, scientists have found that some of them contain tiny crystals of a mineral called zircon. Dated at 4.4 billion years, they are the oldest crystals known on Earth.

EARTH

▲ *MAGMA erupting onto the surface cracks as it cools. The whole of the planet once looked like this.*

## RISING HEAT

Below the surface, the mantle moves very slowly. Scientists think that currents of heat rise from the lower mantle, cool as they near the surface, and then sink back down again. This has a dragging effect on the surface layers, carrying them along like a conveyor belt.

**Earth's metal core** provides the heat.

It contains radioactive elements that give out heat as they become more stable. Even though the inner core is very hot, the huge pressure keeps it solid. The slightly cooler outer core is liquid.



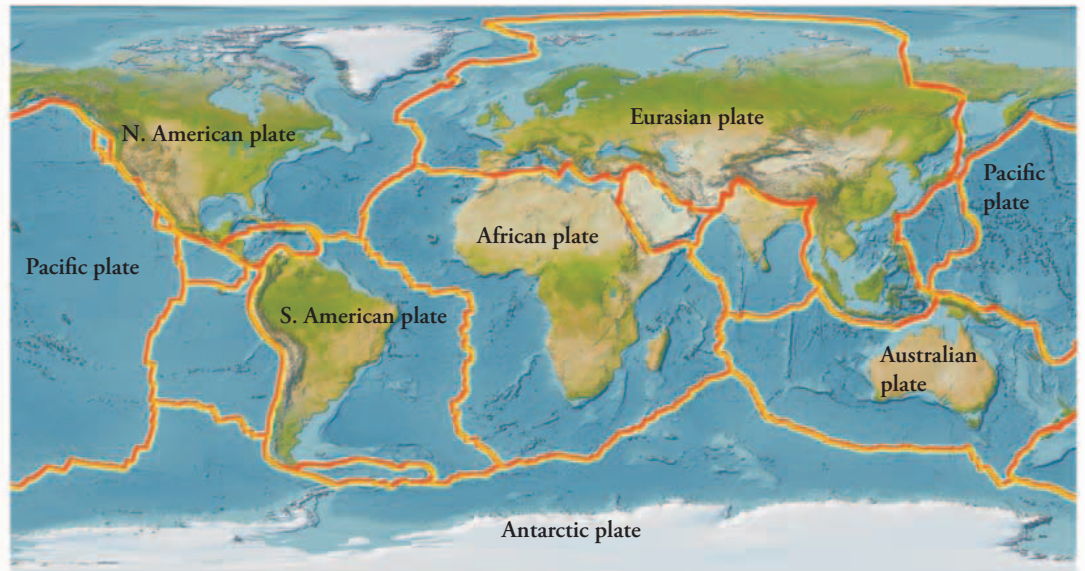
## EARTH'S CRUST

The uppermost surface of Earth is called the crust.

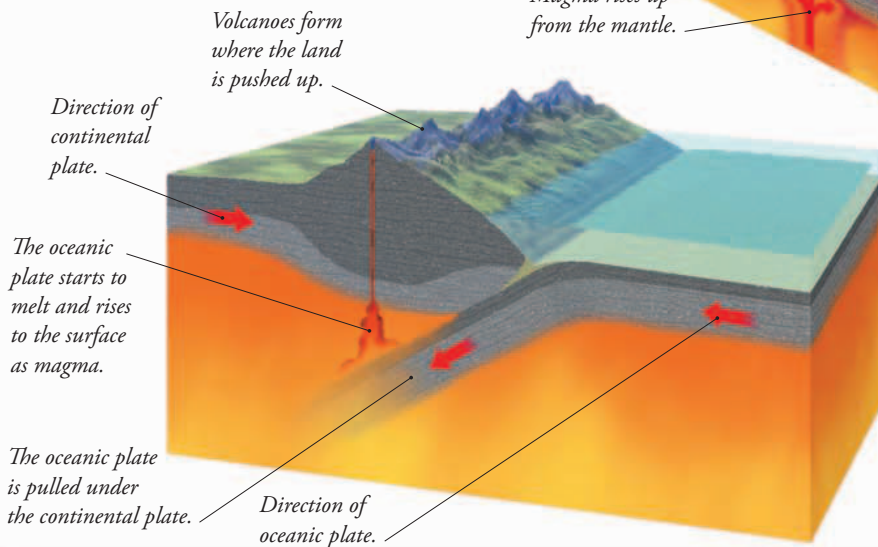
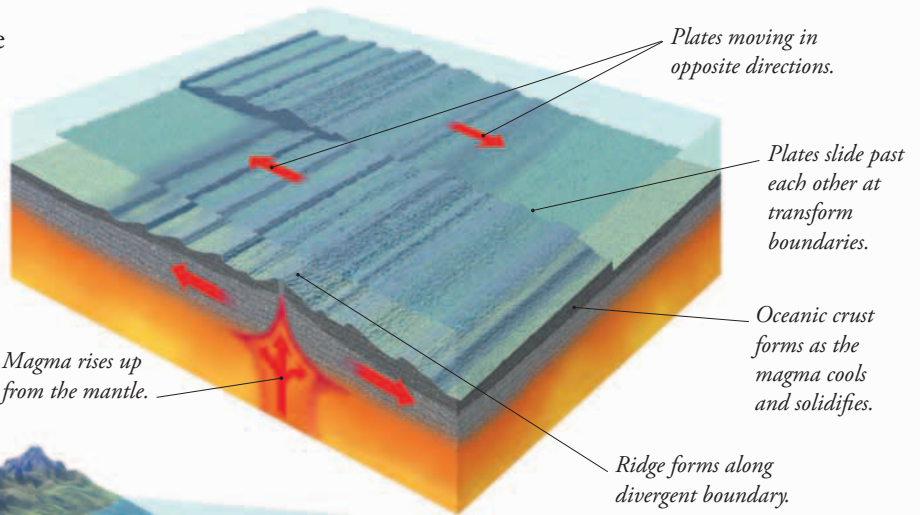
It has two layers: a light top layer and a slightly thinner but denser bottom layer.

The crust is broken into pieces that fit together like a jigsaw puzzle. These plates float on the mantle.

As the mantle moves, the plates go with it.



**Divergent boundaries** At the points where the mantle currents rise upward, the plates above them get pulled apart (diverge). Some of the mantle melts to form magma and fills the gap between the plates. Each time this happens the plates move apart. Sometimes the plates simply slide past each other without any volcanic activity. These are called transform boundaries.



**Convergent boundaries** When two plates meet (converge), one of the plates is pulled under the other. If a continental plate meets an oceanic plate, the denser oceanic plate gives way. If two oceanic plates meet, the cooler, older plate is dragged under. Should two continental plates collide, the rocks on both sides bend and fold to form mountains.

### TAKE A LOOK: PLATE MOVEMENTS

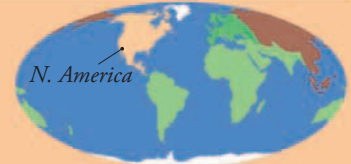
The continents have not always been in the positions they are today. Since Earth's crust cooled they have split, collided, rotated, and reformed. They are still moving about 6 in (15 cm) a year.



▲ About 225 million years ago all the continents were joined together.



▲ Over time, the plates beneath began to pull the continents apart.



▲ Today, the continents look like this, but they are still on the move.

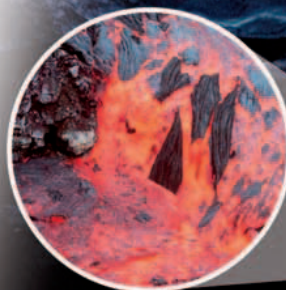


# Volcanoes and earthquakes

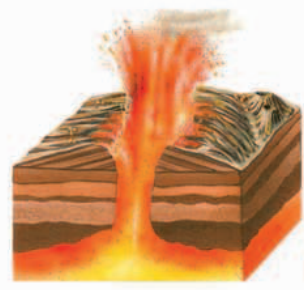
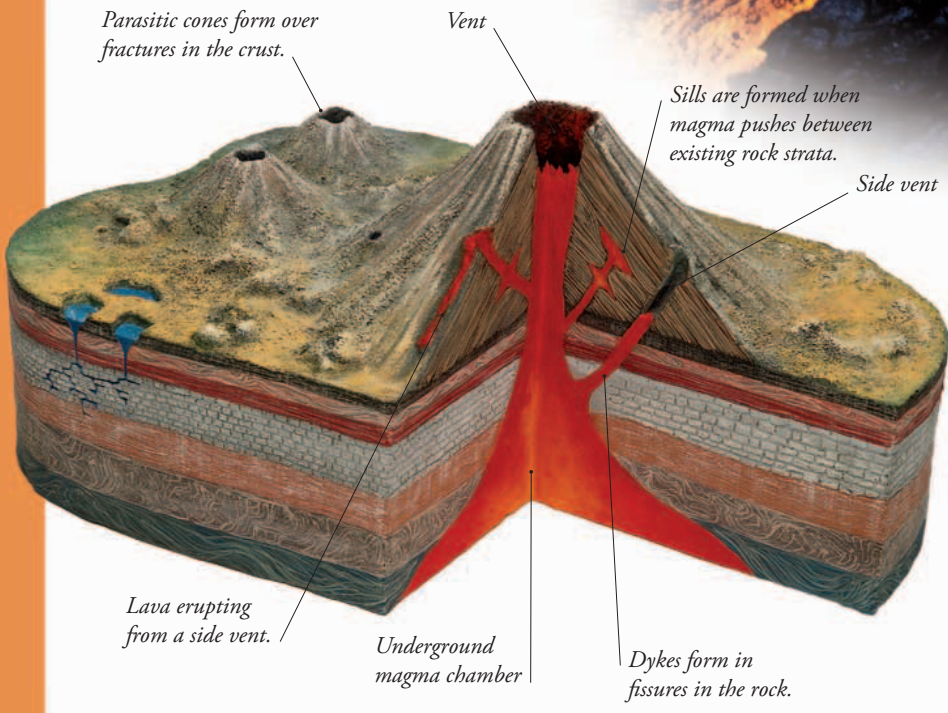
People have always been terrified by the fiery power of volcanoes and earthquakes shaking the ground. Although these are just the natural movements of our planet, they can be highly destructive.

## VOLCANOES

Volcanoes form when molten rock pushes up through the Earth's crust. When molten rock is underground it is called magma, but when it flows onto the surface it is called lava. Some volcanoes erupt gently, but others can be explosive, blasting gas, ash, and rock into the air. Volcanoes may erupt at regular intervals, while others lie dormant for centuries.



▲ **MOLTEN LAVA**  
Lava that does not contain much gas flows over longer distances.



▲ **SHIELD VOLCANO** These are broad, low-profile cones. They are formed when runny lava flows over a long distance before it cools and hardens.



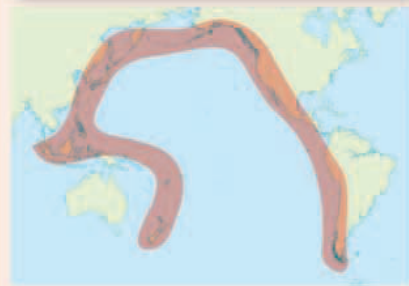
▲ **CINDER CONE** Most volcanoes are cinder cones. They are made of ash and lava blown into fragments by escaping gas.





**Ash clouds** blast fine particles high up into Earth's atmosphere, where they can affect the world's weather for months.

## RING OF FIRE



■ The "ring of fire" lies around the rim of the Pacific Ocean. It is an area where a number of crustal plates meet, resulting in frequent volcanic and earthquake activity. There are 452 volcanoes in the ring, and 80 percent of the world's largest earthquakes occur in this area.

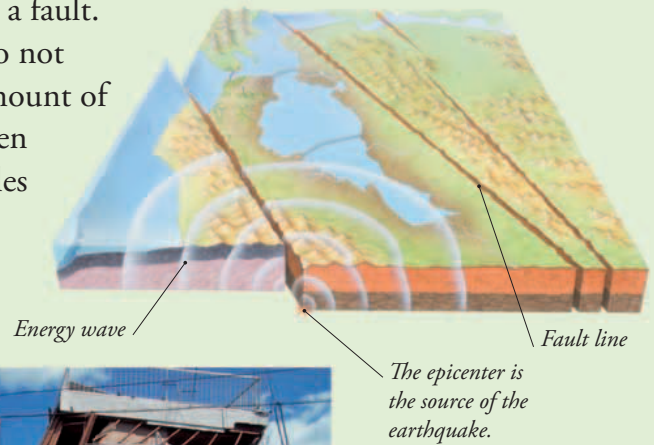


▲ **COMPOSITE VOLCANO** These cones rise steeply toward the summit. They are the most deadly type because they usually erupt explosively.

## EARTHQUAKES

Earthquakes occur when two blocks of the Earth's crust slip past each other. The place where this happens is called a fault.

Because the blocks do not slide easily, a large amount of energy is released when they move. This ripples away like waves on a pond, shaking the ground above.



◀ **ON SHAKY GROUND** When the ground shakes, buildings and other structures may collapse. The strength of an earthquake is measured using the Richter scale. This earthquake in Kobe, Japan, measured 7.3 on the scale. It lasted for only 20 seconds, but it made 200,000 buildings fall down.

## Tsunami

■ **Tsunamis** are giant ocean waves caused by a sudden movement of the ocean floor. Sometimes colliding plates get stuck. When they finally release, it can trigger an earthquake, which gives the overlying water a huge shove. The waves grow stronger as they cross the ocean and cause devastation when they hit land.



▲ **WORLDWIDE WAVE** The tsunami of 2004 began with an earthquake off the coast of Indonesia. The wave was eventually felt as far away as Iceland and Chile.



▲ **BEFORE** Banda Aceh in Indonesia was close to the epicenter of the 2004 earthquake and was the first place the tsunami struck.



▲ **AFTER** Most of the northern shore was submerged by the tsunami. More than 230,000 people in eleven countries died when the waves hit land.



# Making mountains

Mountain ranges cover about a fifth of the Earth's land surface. They have built up over millions of years, as massive tectonic plates crash into one another. Many ranges, such as the Himalayas, are still being pushed upward.

## LIFT AND FOLD

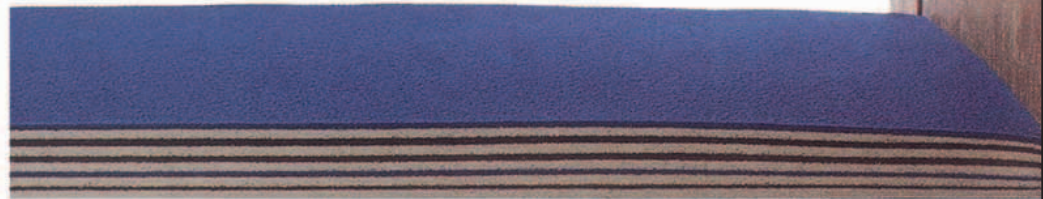
Most mountains are fold mountains, which have been created by the movement of tectonic plates across the Earth's surface. When two tectonic plates push against each other, the rock of the Earth's crust lifts up and folds over on itself. The folds get bigger and bigger over time.



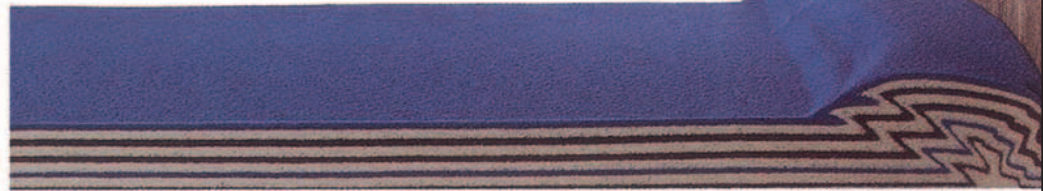
▲ **CROSS SECTION** *This cliff face in Dorset, England, shows how rock strata twisted and folded over as the African and European plates collided millions of years ago. This same collision gave birth to the Alps.*

**Shifting sand** This experiment below uses layers of sand on a sheet of paper to show how rock strata buckle and double over as a mountain forms. Each layer of sand represents a layer of the Earth's crust. The paper is pulled along slowly, at a rate of ½ inch (1 cm) per 100 seconds. As the paper moves, it drags the sand with it. This is similar to the way the Earth's slowly flowing upper mantle pulls along the crust.

▼ **SEDIMENTS** *Layers of sediment are laid down evenly on top of the paper.*



▼ **ZIGZAGS** *The moving paper makes wrinkles in the bottom layer of sand. These are magnified into Z-shaped folds in higher layers.*



▼ **HIGHER AND HIGHER** *The sand folds build up on top of each other, making large loops.*



## FACT FILE

- Mountains are home to approximately one-tenth of the world's people.
- Mountains occur in 75 percent of the world's countries.
- Many mountains are permanently capped in ice and snow.
- For every 330 ft (100 m) you climb upward, it gets 2°F (1°C) cooler.
- The strongest wind recorded on a mountain was 231 mph (372 km/h) on Mt. Washington, New Hampshire.



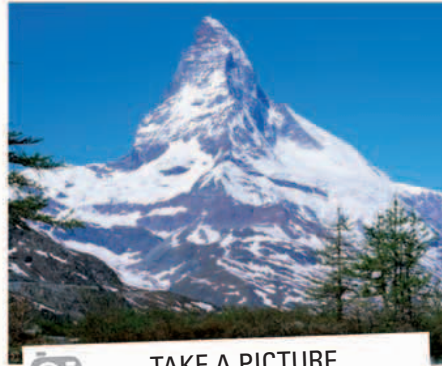
▲ **MOUNTAIN MACHINE** *The paper and sand are held between fixed wooden blocks inside a tank.*



**TYPES OF MOUNTAIN**

Not all mountains are fold mountains. Some are formed by eruptions from volcanoes, and others are made up of massive blocks of rock pushed up as Earth's crust cracks. Mountains are given their jagged appearance by heavy erosion, which strips the rock away from their sides.

**Going up** The higher you climb, the air becomes thinner and the temperature gets colder. The tree line marks the cut-off point beyond which it is too cold for trees to grow.



**TAKE A PICTURE**

The Matterhorn is an easily recognizable peak in the Alps. It was first climbed in 1865 by an English mountaineer, Edward Whymper.



**FAMOUS MOUNTAINEERS**

- Sir Edmund Hillary and Tenzing Norgay were the first climbers to reach the summit of Mount Everest. They did so on May 29, 1953. Hillary was a New Zealander, and Norgay was Nepalese.
- Lino Lacedelli and Achille Compagnoni were Italian mountaineers and the first people to conquer K2. They reached its peak on July 31, 1954.
- Richard Bass was the first person to climb the "Seven Summits"—the tallest mountains on each of the world's seven continents. He finished on April 30, 1985.



**MT EVEREST (SAGARMATHA)**

**Nepal–China**  
29,029 ft (8,848 m)

**K2 (MT GODWIN AUSTEN)**

**Pakistan–China**  
28,251 ft (8,611 m)

*A SAVAGE MOUNTAIN One in four people die when they try to reach the summit of K2.*

**ACONCAGUA**

**Argentina**  
22,835 ft (6,960 m)

**KILIMANJARO**

**Tanzania**  
19,341 ft (5,895 m)

**MELTING ICE-CAP**

*It is estimated that the ice-caps on Mount Kilimanjaro will have melted by 2020.*

**MT MCKINLEY**

**United States**  
20,322 ft (6,194 m)

**MATTERHORN (CERVINO)**

**Italy–Switzerland**  
14,692 ft (4,478 m)

**MT FUJI**

**Japan**  
12,388 ft (3,776 m)

**MONT BLANC**

**France–Italy**  
15,770 ft (4,807 m)

*AN ACTIVE VOLCANO The last eruption of Mount Fuji was in 1707–1708, when it erupted for 16 days. Some scientists believe that it may erupt again soon.*

**MT COOK (AORAKI)**

**New Zealand**  
12,349 ft (3,764 m)

**NAMED BY AN EXPLORER**

*Mount Cook was named by the explorer Captain James Cook. Its original, Maori name is Aoraki.*

**VESUVIUS**

**Italy**  
4,190 ft (1,277 m)

*OTHER NAMES Mountains often have different names in different languages. The Matterhorn is so-called in English and German, but in Italian it is called Cervino and in French, Mont Cervin.*

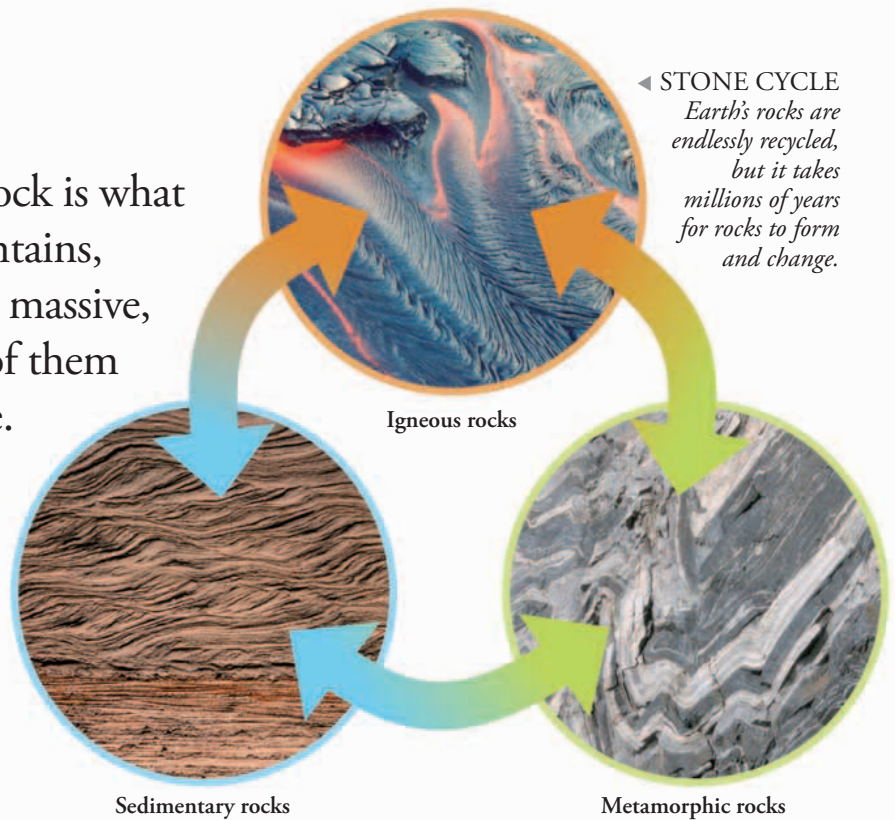


# Rocks

Our planet is a big ball of rock. Rock is what gives the Earth its features—mountains, canyons, and plains. Rocks can be massive, or as small as a grain of sand. All of them started life deep inside the mantle.

## WHAT IS A ROCK?

Rocks are usually made up of several different minerals. Looking closely at a rock can tell you a lot about its history. The shapes of crystals or grains in the rock and how they fit together reveal whether the rock is one of three types: igneous, metamorphic, or sedimentary.



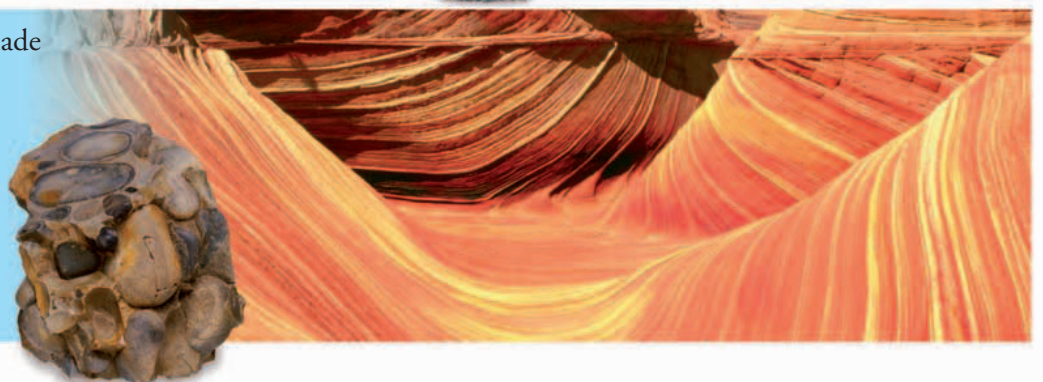
**Igneous rocks** began as molten rock deep inside Earth. They are the most common rocks in the Earth's crust. Some were erupted onto the surface as lava; others solidified underground. The speed at which they cooled is shown by the crystals they contain—big crystals indicate slow cooling.



**Metamorphic rocks** These began as other types of rock but have been altered by great heat, pressure, or both, deep inside the Earth's crust. Most of the minerals in the original rock have changed. These rocks often show folded or squashed bands.



**Most sedimentary rocks** are made of small particles of other rocks, transported by water, wind, or ice. The particles may all be the same size or a mixture of sizes. These build up in layers, and pressure from new layers above squashes them into hard rock.





# Minerals

When Earth first formed, it inherited many different chemical elements. Over billions of years, these elements combined to form thousands of different chemical compounds.

## WHAT IS A MINERAL?

Minerals are the building blocks of every type of rock. They consist of a single chemical element or a compound of mixed elements. There are about 4,000 different minerals, but only 100 occur in any great quantity.

**Types of mineral** The common minerals that make up Earth's crust are called "rock-forming minerals." They are mostly compounds of the elements silicon and oxygen. Other minerals are "ore minerals"—they contain large amounts of mainly metallic elements that are very useful to us.

**How minerals form** Most minerals form when molten rock or a hot solution cools and forms crystals. The crystals that form are affected by pressure and temperature, so a mineral can look different depending on how it crystallizes. However, some minerals, such as coal and chalk, start off as living organisms.

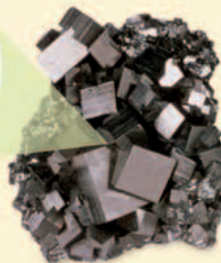


◀ **DIAMOND** is made of pure carbon. It is the hardest mineral on Earth.

◀ **CHALCOPYRITE** is a copper and iron sulfide ore seen here mixed with clear quartz crystals.

## CRYSTALS

Most minerals are crystals. The atoms in the minerals are arranged in regular patterns, which give crystals their simple geometrical shapes. The crystal structure affects many of the mineral's physical properties, such as hardness, and how the crystal fractures.



▲ **GALENA** is the name given to lead sulfide. Its crystals are cubic in shape. If it is hit with a hammer, the crystals break off into smaller cubes.



▲ **CINNABAR** is a sulfide of mercury that forms hexagonal crystals.



## WHAT USE IS A MINERAL?

Minerals have a huge range of practical uses...

- They can be mined to extract metals (for example, copper, gold, or silver).
- Minerals like potash and apatite can be used as plant fertilizers.
- Crystals can be cut and polished into gemstones (diamond, ruby, emerald).
- Colored minerals are used as pigments.
- Some minerals are used in bath or beauty products.





# Rock and mineral guide

Collecting rocks and minerals can be a rewarding hobby. Rocks are identified by features like color, texture, and mineral content. Minerals are classified by crystal structure, hardness, and how they break.

## KEY

Rocks are graded by the size of their grains, as either fine, medium, or coarse. The size limits for each category vary depending on whether rocks are igneous, metamorphic, or sedimentary (👁️ p.38).

- F** = fine
- M** = medium
- C** = coarse

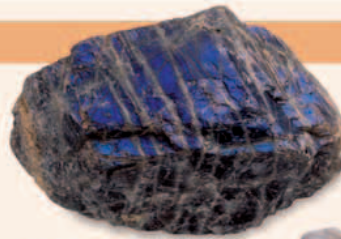
## IGNEOUS ROCKS



**F** Obsidian



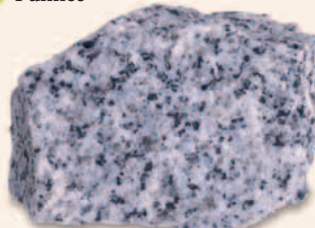
**F** Pumice



**F M C** Anorthosite



**M C** Kimberlite



**C** Granite

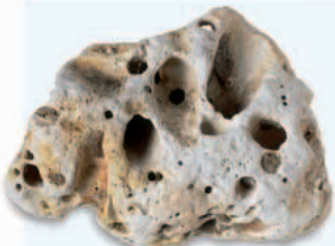


**C** Pegmatite



**C** Peridotite

## SEDIMENTARY ROCKS



**F** Chalk



**F M** Siltstone



**F M C** Limestone



**C** Tillite



**C** Conglomerate

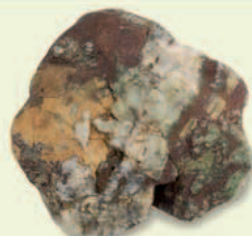
## METAMORPHIC ROCKS



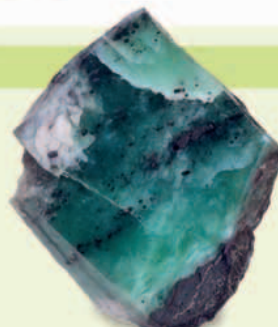
**F** Slate



**F M** Quartzite



**F M C** Marble



**F M C** Serpentinite



**M C** Schist



**M C** Gneiss



MOHS' SCALE

One way of telling the difference between similar-looking minerals is to test their hardness. This is measured by scratching minerals against each other. A hard mineral can always scratch a softer one. The hardest mineral is diamond.



ORES



SEMI-PRECIOUS STONES



PRECIOUS STONES

■ Gemstones are divided into precious and semi-precious stones based on value. The four that qualify as precious are diamond, emerald, sapphire, and ruby.





# Riches from the Earth

Many useful materials are hidden away below the Earth's surface. Some of these rich resources, such as precious metals and gemstones, have been used since ancient times. Others, such as fossil fuels, are more recent discoveries, but equally important.

## FAST FACTS

- South Africa is one of the world's leading mining nations, holding large reserves of gold, diamonds, and other valuable mineral resources.
- By 2015, the world demand for oil will be about 96 million barrels a day.
- Saudi Arabia is the world's leading oil producer.
- Mining kills and injures more workers than any other industry.

▼ **IRON MINE**  
Iron ore mines in Brazil are some of the most productive in the world.



◀ **HEMATITE**, the mineral form of iron oxide, is identified by its rusty red streaks.

## MINING

People need to dig up the resources from the Earth's crust before they can use them. This is called mining. There are two main techniques, depending on the types of mineral being extracted. They are surface mining, or quarrying, and underground mining.



▲ **DRILLING FOR GOLD** A miner drills for deposits of gold at a mine in South Africa. The rock face lies deep underground, and the work is physically demanding and very dangerous.

**Underground mining** Any minerals buried deep beneath the Earth's surface must be extracted using underground mining techniques. Miners use heavy machinery to drill deep shafts under the ground. They lay rails to carry the minerals, drilling gear, waste material, and the miners themselves to and from the rock face. Underground mining is dangerous work and much more expensive than surface mining.

**Surface mining** The largest mines are strip mines, which extract minerals on or near the Earth's surface. Miners use explosives, diggers, and heavy machinery to dig huge holes in the ground. Most of the world's mining output is through surface mining. This type of mining is much safer than underground mining.





## FOSSIL FUELS

Coal, oil, and natural gas are fossil fuels. These vital resources formed from the remains of animals and plants that lived millions of years ago. Over time, the vast pressure and temperature under the ground changed the remains into coal, oil, and natural gas. Fossil fuels now provide most of the world's power.

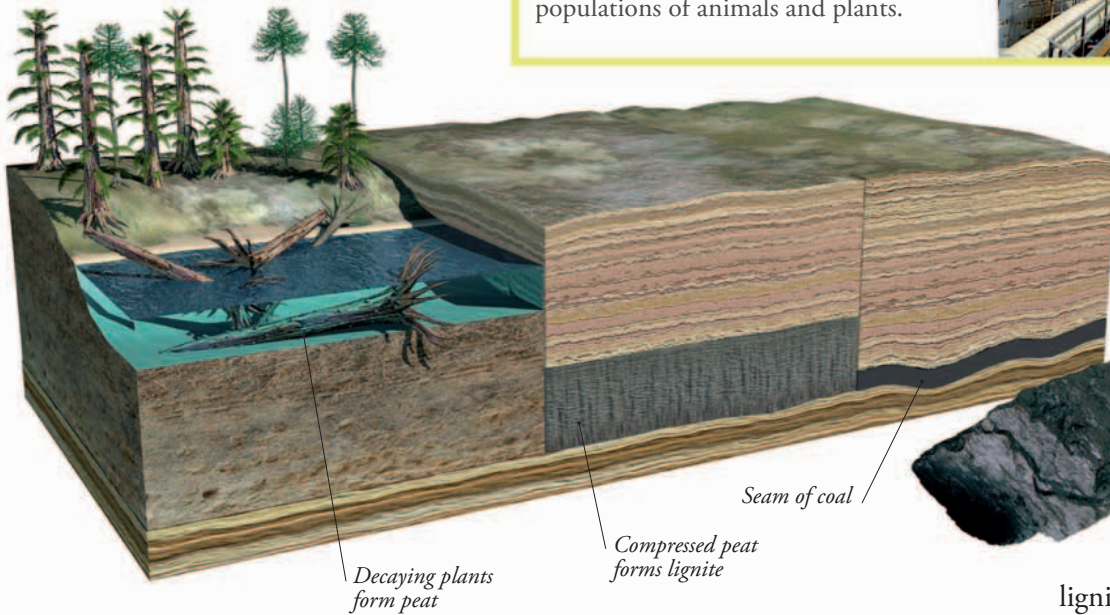


■ **Oil spills** from tankers spread over vast distances in ocean currents. These environmental disasters devastate marine wildlife such as fish and seabirds.

■ **Burning fossil fuels** in car engines and power plants pumps huge volumes of carbon dioxide into the air, which is leading to global warming.

■ **Oil exploration** destroys habitats in wilderness areas, decimating local populations of animals and plants.

## ENVIRONMENTAL CONCERNS

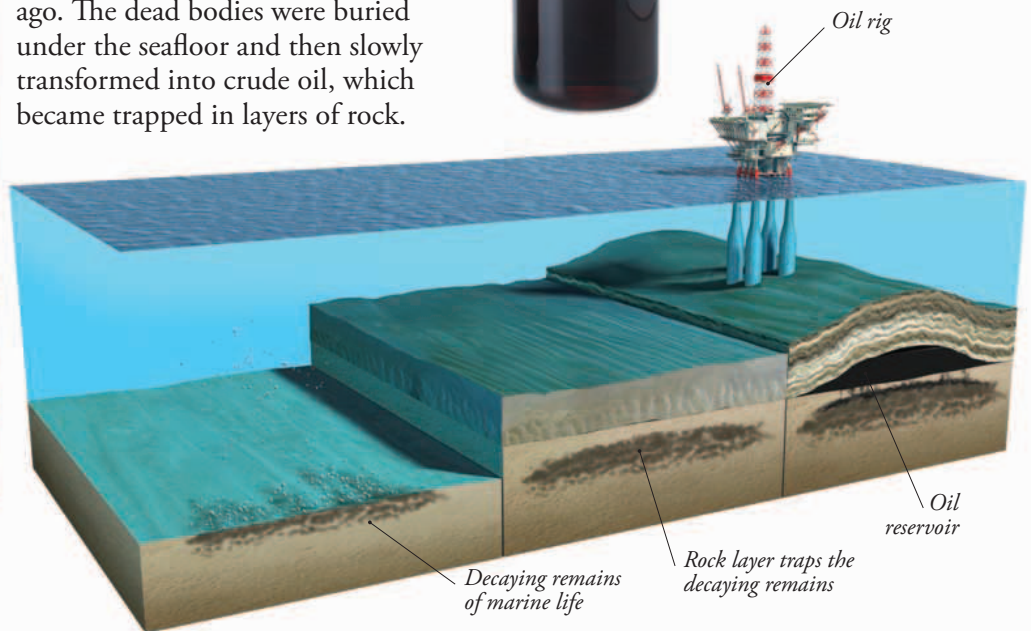


**Coal** This hard black solid forms when peat deposits become buried underground. Peat is a rich type of soil formed from plants and their decaying remains. Over millions of years, the weight of the top layers of peat pushes down on the lower levels. This squeezes the peat, which first turns into a mineral called lignite and eventually into coal.



▲ **STRIKE IT LUCKY** An oil worker guides a giant hydraulic pump into position to extract the crude oil from an oil well.

**Oil** This thick black liquid forms from the remains of marine animals and plants that lived millions of years ago. The dead bodies were buried under the seafloor and then slowly transformed into crude oil, which became trapped in layers of rock.





# Erosion

Earth's landscape is constantly changing, as rock and soil are worn away by the destructive effects of water, wind, ice, and gravity. Erosion can be sudden, such as when a landslide happens. But gradual erosion can be just as dramatic, for example, as rivers carve deep valleys into the Earth's surface.

## WIND EROSION

As wind flows across the land, it lifts up and carries countless grains of sand and other tiny particles. These particles, called sediment, may be blown against rocks at high speeds, grinding away at their surfaces. Over many years wind erosion has the effect of wearing rock into new shapes and resculpting the landscape. Wind erosion happens most in dry, desert regions.

### TELL ME MORE...

What happens to the sediment transported by erosion? Much of it mixes with organic remains and becomes soil. Rivers drop sediment as they lose speed. In time, sediment may become buried and harden into new rock.

#### ▼ WIND SCULPTURES

*Wind erosion wears down soft rock faster than hard rock. As the soft rock disappears, strange shapes are revealed.*

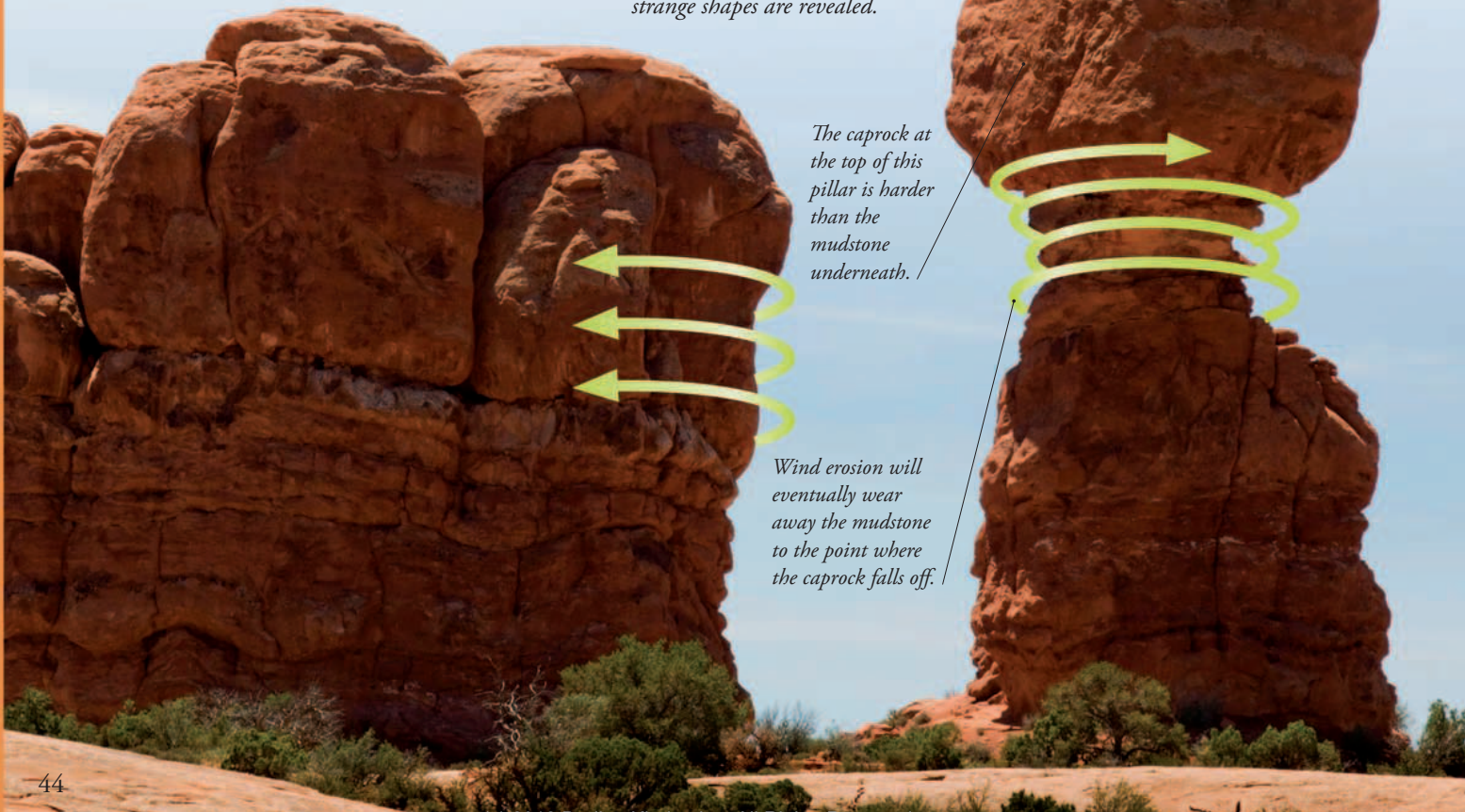
*The caprock at the top of this pillar is harder than the mudstone underneath.*

*Wind erosion will eventually wear away the mudstone to the point where the caprock falls off.*

### LANDSLIDE!



Huge amounts of rock, soil, and mud can suddenly slip down hillsides under the effects of gravity, tearing down trees and burying homes. Landslides may be caused by activities such as tree-felling. Trees' roots hold soil in place, so when forests are cut down, landslides become more likely.

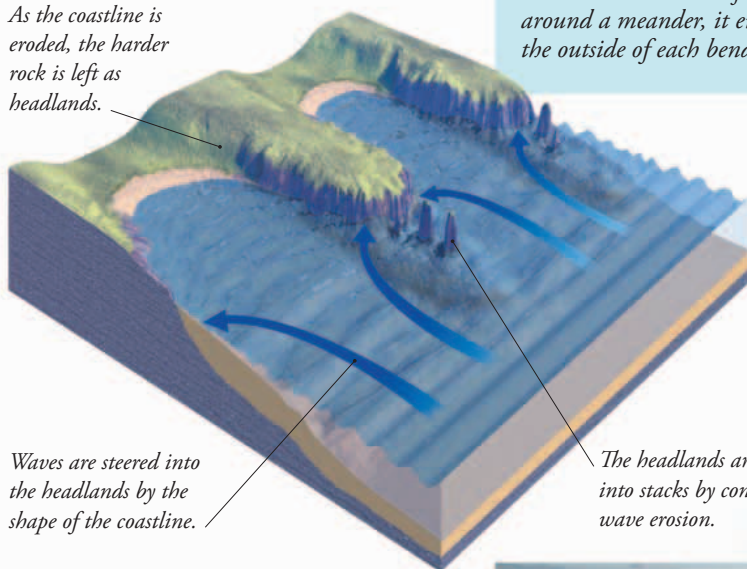




## WATER EROSION

As rainwater flows downhill, it picks up small fragments of rock. These fragments wear channels into the earth, gradually carving out the beds of rivers. In the same way, ocean waves and tides grind down the rocks of the shoreline, creating bays, headlands, cliffs, and rock pillars called stacks.

As the coastline is eroded, the harder rock is left as headlands.



Waves are steered into the headlands by the shape of the coastline.

The headlands are worn into stacks by constant wave erosion.

## ICE EROSION

About 10 percent of Earth's land surface is covered by slow-moving masses of ice called glaciers. As glaciers move, rocks trapped in the ice scour the land, wearing it smooth. Water can also split rocks as it freezes, since water in cracks expands as it turns to ice.

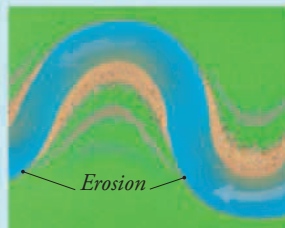


▲ DEPOSITION The sediments transported by rivers and by ocean tides can be deposited in large quantities, creating new land features such as this spit.

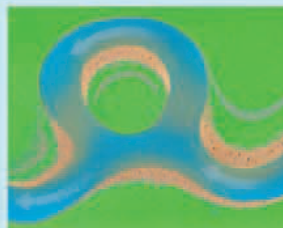


### TAKE A LOOK: THE POWER OF WATER

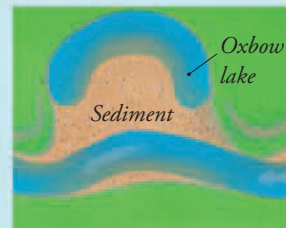
Rivers constantly erode away the rock of their own beds, which gradually changes their courses. This can create features such as oxbow lakes.



▲ STEP 1 As a river flows around a meander, it erodes the outside of each bend.



▲ STEP 2 The bends gradually change shape, until a shortcut is created.



▲ STEP 3 Sediment deposited by the river cuts off the meander.

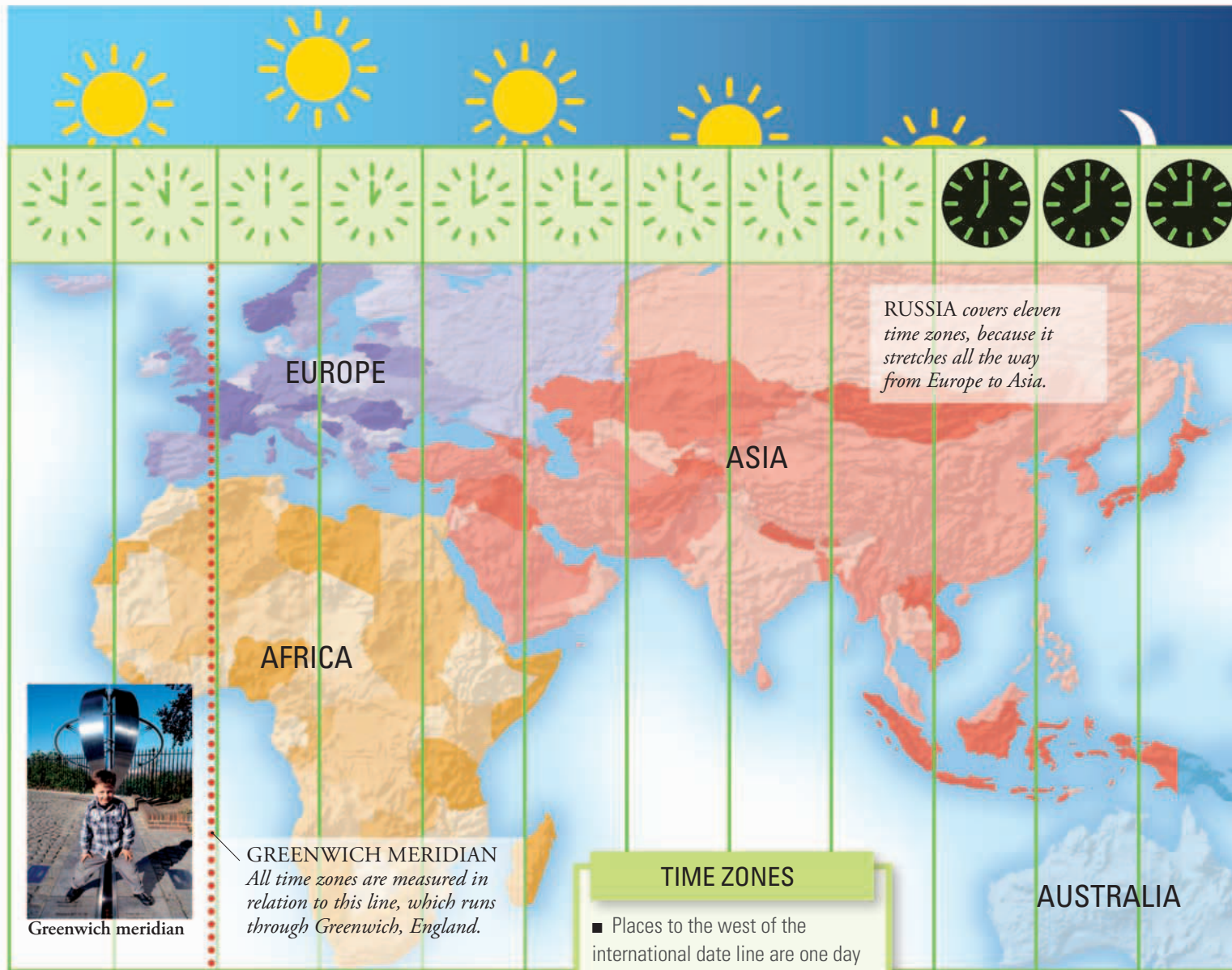
► TWELVE APOSTLES These rock formations off the coast of Victoria, Australia, were created by the sea eroding limestone headlands.





# A look at time

What time is it right now? The answer depends on where you are. If it's noon in Santiago, Chile, it will be midnight in Perth, Australia. To make sense of this, the world is divided into 24 time zones, and clocks in each zone are set to the same time.



Greenwich meridian

**GREENWICH MERIDIAN**  
*All time zones are measured in relation to this line, which runs through Greenwich, England.*

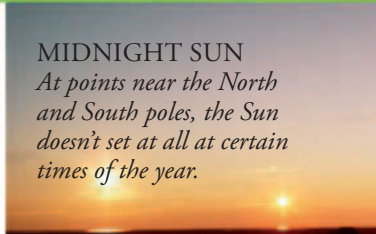
*RUSSIA covers eleven time zones, because it stretches all the way from Europe to Asia.*

## TIME ZONES

- Places to the west of the international date line are one day ahead of places to the east.
- Many countries move an hour ahead in the summer so there is more light in the evenings. This is called daylight saving time. However the practice isn't always popular with farmers, who need light in the early morning.



**Party time!** One of the first populated places to celebrate the New Year each year is Kiribati in the Christmas Islands. Hawaii, which is to the east of the international dateline, is one of the last places to join the party.



**MIDNIGHT SUN**  
*At points near the North and South poles, the Sun doesn't set at all at certain times of the year.*



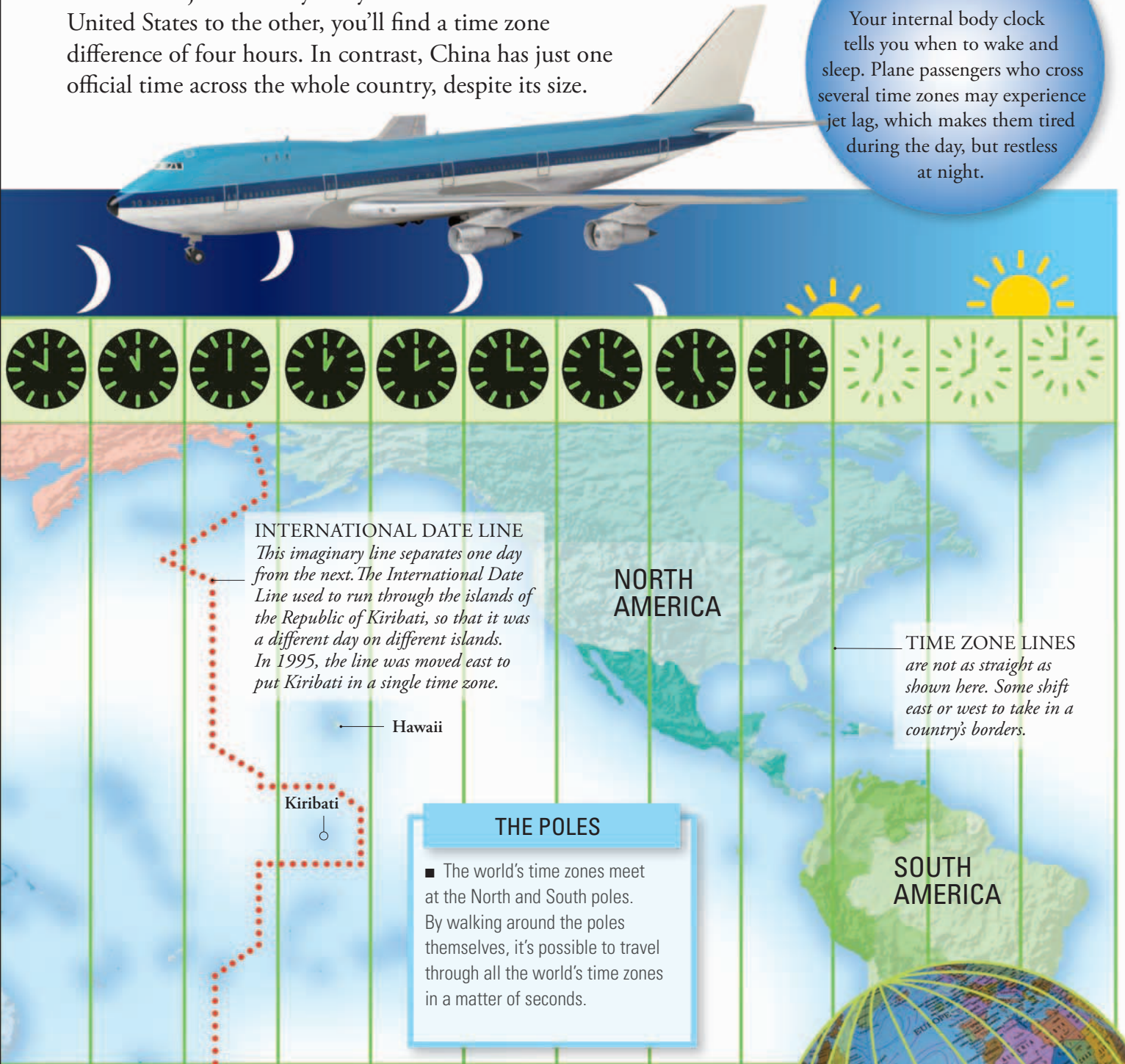
## THE TIME BELOW IS...

Some countries are split into several time zones, whereas others lie in just one. If you fly from one side of the United States to the other, you'll find a time zone difference of four hours. In contrast, China has just one official time across the whole country, despite its size.

**WOW!**

Your internal body clock tells you when to wake and sleep. Plane passengers who cross several time zones may experience jet lag, which makes them tired during the day, but restless at night.

EARTH



**Time traveler** The system of worldwide, standardized time zones was first proposed by Canadian Sir Sandford Fleming in 1878. He pointed out that the world is divided into 360 degrees of longitude (imaginary lines running from north to south), and that these could be split into 24 time zones of 15 degrees each.





# Precious water

Without water, life on Earth could not exist. This vital resource fills the world's oceans, lakes, and rivers or soaks into the earth to form groundwater. A small fraction of the world's water exists as ice or water vapor in the air, or is held inside the bodies of animals and plants.

**FAST FACTS**

- The Caspian Sea is the largest inland body of water in the world.
- Lake Baikal in Siberia is the world's deepest freshwater lake and the largest by volume.
- Lake Superior in North America has the largest surface area of any lake in the world.
- The Dead Sea on the border of Israel and Jordan is the world's lowest lake and also one of the saltiest.

## FRESH WATER

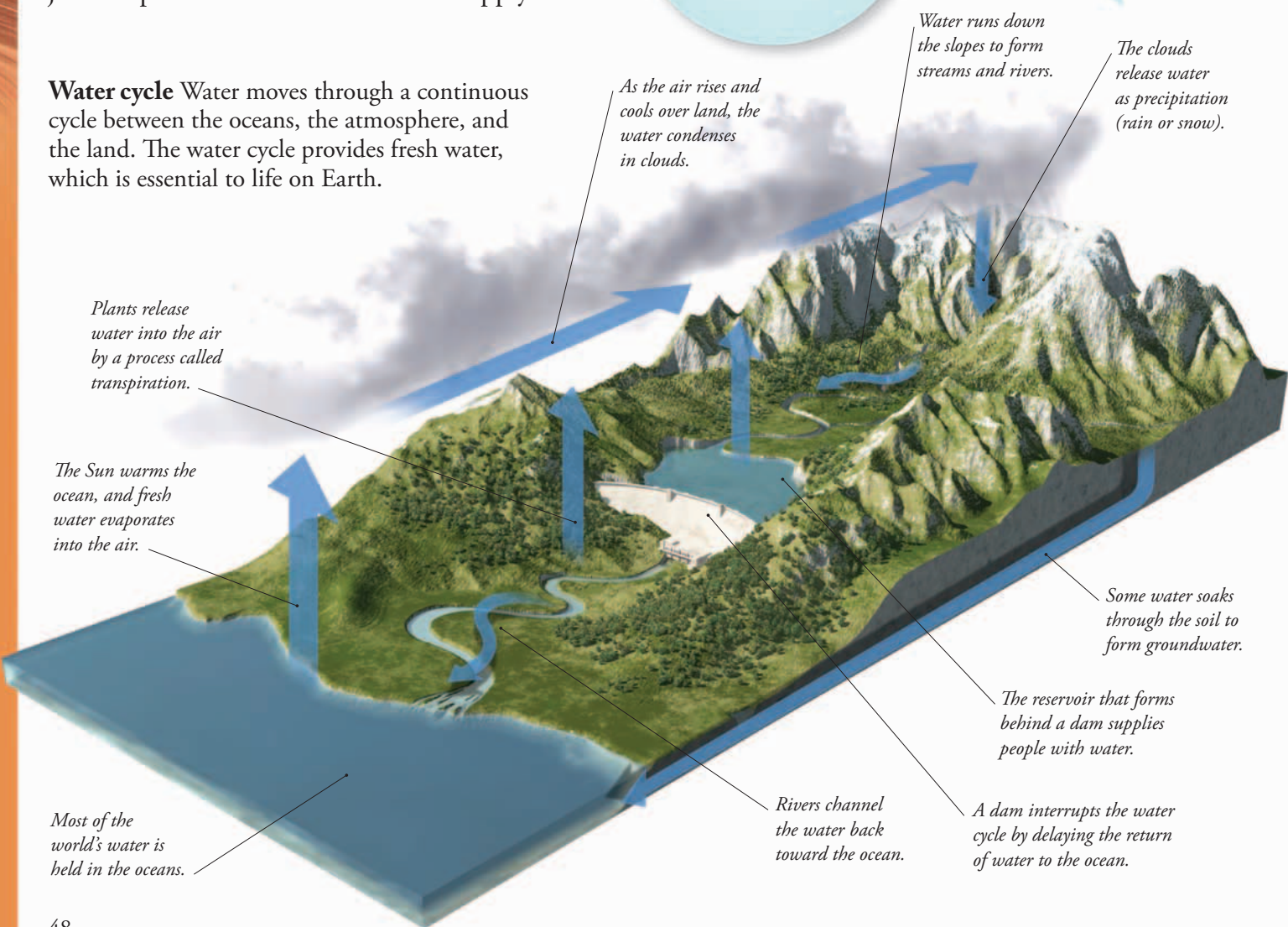
The salty seas and oceans make up 97 percent of the world's water. The rest is fresh water, and most of it is locked away in the polar ice caps and glaciers. The fresh water we drink comes from lakes, ponds, and rivers and accounts for just 0.6 percent of the world's water supply.

**WOW!**

The Earth's oceans contain 324 million cubic miles (1.36 billion cubic kilometers) of water.

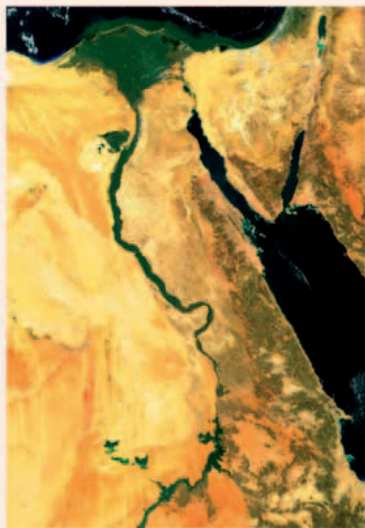
Only 3 percent of Earth's water is fresh water.

**Water cycle** Water moves through a continuous cycle between the oceans, the atmosphere, and the land. The water cycle provides fresh water, which is essential to life on Earth.





## WORLD'S LONGEST RIVERS



▲ *The Nile River was the lifeblood of the ancient Egyptians, providing the water to grow their crops.*

The world's longest rivers (by continent) are:

- **Nile:** Africa's longest river, at 4,135 miles (6,650 km).
- **Amazon:** At 4,000 miles (6,400 km), the longest river in South America.
- **Yangtze:** Asia's longest river, at 3,915 miles (6,300 km).
- **Mississippi:** At 3,902 miles (6,275 km), the longest river in North America.
- **Volga:** Europe's longest river, at 2,294 miles (3,692 km).
- **Murray–Darling:** At 1,701 miles (2,739 km), the longest river in Australia.

**Underground water** Some of the water that falls as rain seeps into the soil and into the rocks below to become groundwater. Some rocks soak up water and form a saturated layer called the water table. But water can also leak through cracks in rocks and form pools in underground caves.



► **BLIND CAVEFISH**

*These fish live in deep caves and rely on touch, rather than sight, to sense their surroundings.*



## WATER

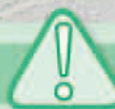
- There are approximately 75,000 dams in the United States alone.
- Las Vegas gets 85 percent of its water from Lake Mead—the vast reservoir behind the Hoover Dam.
- At 1,000 feet (300 meters) tall, Nurek Dam in Tajikistan is the world's tallest dam.



▲ **WATER SUPPLY** *Lucky Peak Dam traps water from the Boise River in Idaho.*



**Solid water** Some water falls from clouds as snow. In the polar regions, and high in the mountains, the snow builds up in layers that push down to form an icy mass called a glacier. The glacier flows to the sea and breaks up into icebergs, which gradually melt, and the water cycle starts all over again.



## SAVE FRESH WATER

- Running faucets uses up a lot of water, so turn them off when you have finished.
- Only flush the toilet when you have to.
- Take a shower instead of a bath because it uses up much less water.
- Keep waste water from sinks and bathtubs and use it to water plants in the garden.





# The world's oceans

Earth is known as the “blue planet,” after the oceans that cover two-thirds of its surface. Much of the ocean remains mysterious because the dark, cold conditions make its deep waters difficult to explore.

## MIGHTY OCEANS

Our oceans are in constant motion. They are driven by flowing currents that mix warm and cold water, which in turn affect our climate. There are five great oceans. In order of size, these are the Pacific, Atlantic, Indian, Southern, and Arctic oceans. Smaller areas are called seas.

▼ **WAVE POWER** *Waves contain a huge amount of energy. This energy can be captured and turned into electricity.*

### TELL ME MORE...

Twice a day the sea level rises and falls. This movement is called a tide. It is caused by the gravitational effects of the Moon, Sun, and Earth. When these combine, a bulge of water forms on either side of Earth, causing a high tide. When it passes, the tide goes out.

#### North Sea

*Average depth 308 ft (94 m)*

#### Arctic Ocean

*Average depth 3,248 ft (990 m)*

#### Mediterranean Sea

*Average depth 4,921 ft (1,500 m)*

#### World oceans

The depth of the ocean varies enormously. On average, the Southern Ocean is the deepest, but many oceans have submarine canyons running through them. The deepest of these is the Mariana Trench in the Pacific. At 35,829 ft (10,920 m) deep, you could fit in Mount Everest with room to spare.

#### Caribbean Sea

*Average depth 4,960 ft (1,512 m)*

#### Atlantic Ocean

*Average depth 10,925 ft (3,330 m)*

#### Indian Ocean

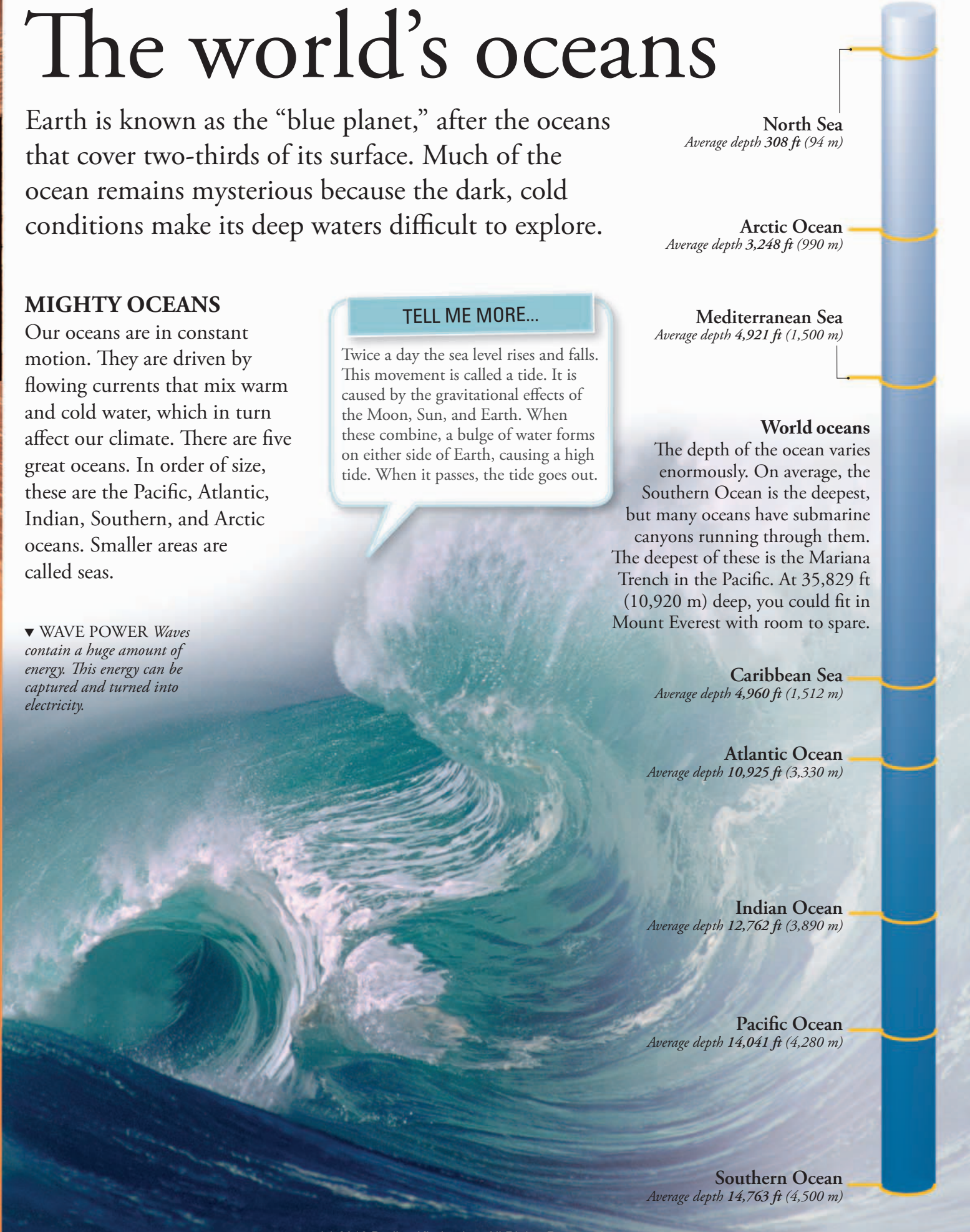
*Average depth 12,762 ft (3,890 m)*

#### Pacific Ocean

*Average depth 14,041 ft (4,280 m)*

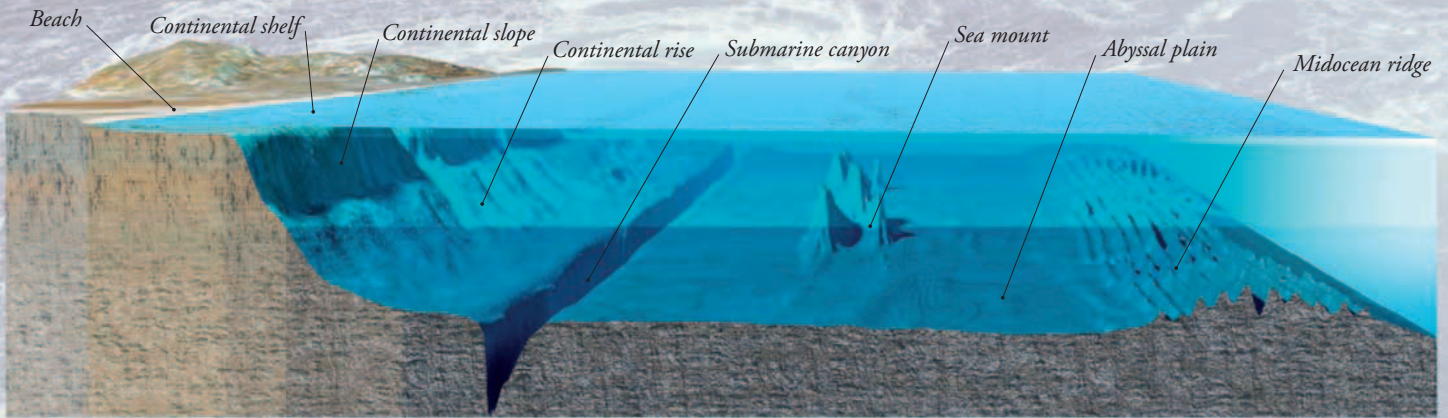
#### Southern Ocean

*Average depth 14,763 ft (4,500 m)*

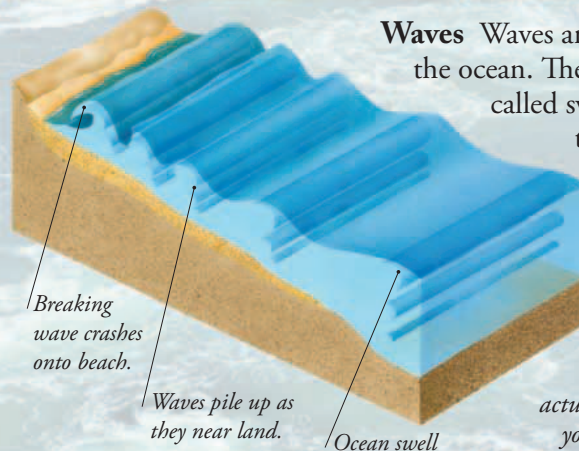




**Ocean circulation** The circulation of the ocean partly controls climate, because warm or cold air masses move with ocean currents. The Gulf Stream takes warm, salty water from the Caribbean to the Nordic seas and brings mild weather to northern Europe. Without the Gulf Stream, winters in Lisbon, Portugal, would be more like winters in New York, which is a similar distance from the North Pole. Around Iceland, the Gulf Stream's salty water gets cold and heavy and sinks down, sucking more warm water from farther south to replace it. That deep cold water flows from the Arctic to the Southern Ocean, where it meets an even deeper cold current flowing eastward around Antarctica. Similar processes take place in the Indian and Pacific oceans.



**Continental margins** The land does not stop when it meets the ocean. The continental shelf extends out for about 650 ft (200 m) then slopes sharply down to the ocean floor. Although large areas of the floor, or abyssal plain, are flat, it is not featureless. There are deep canyons and trenches, volcanic sea mounts, and spreading ocean ridges.



**Waves** Waves are caused by winds blowing over the ocean. These produce smooth, large waves called swells. As they get closer to shore they begin to pile up. The depth between the wave and the seafloor becomes shallower, causing the wave to break into a foamy crest that crashes onto the beach.

▼ **BUOYED UP** Some "seas" are actually salty lakes. The Dead Sea is so salty you can float without making any effort.

**DEEP, BLUE SEA**



Life at the bottom of the **deep ocean** is hard. The weight of water above is so heavy it can crush organisms that use lungs to breathe. It is dark because light cannot reach very far, which also makes it cold. Animals that live here need special adaptations to help them survive.

**Salt water** As everyone knows, seawater tastes salty, and will make you thirsty if you try to drink it. Not only is common salt (sodium chloride) found in seawater, but many other minerals as well. There is even a little dissolved gold. Scientists estimate there could be as much as 50 million billion tons (tonnes) of dissolved salts in the sea. If this were spread on the land it would measure 500 ft (150 m) deep.



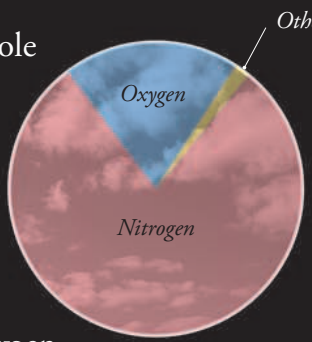


# Atmosphere

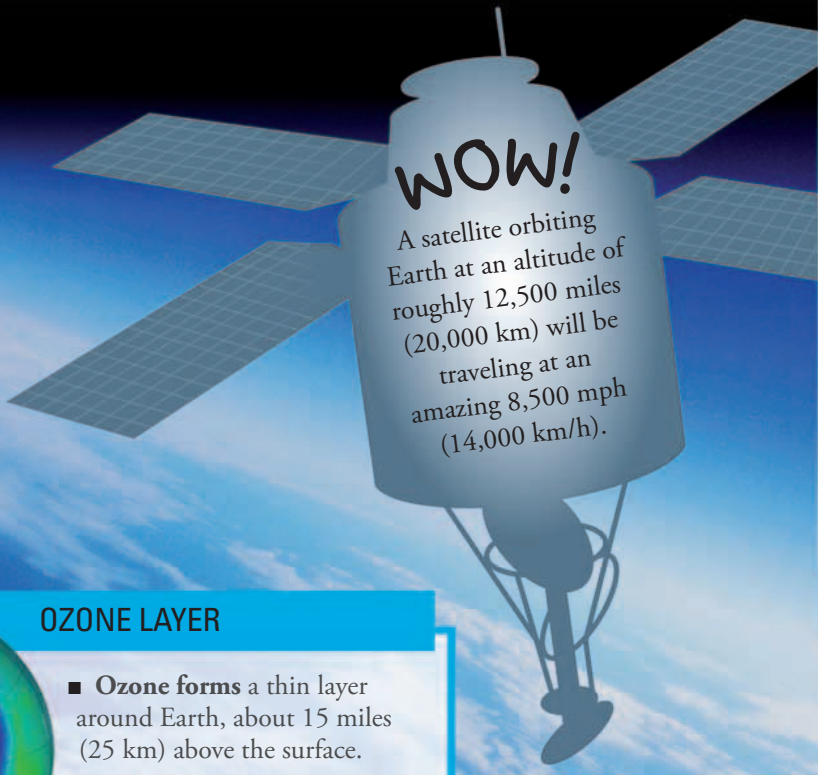
Life on Earth could not exist without the thick blanket of gases that surrounds the planet. This “atmosphere” is a complex, dynamic system that interacts with the oceans, land, and the Sun to create our weather and climate.

## PROTECTING EARTH

The atmosphere plays a vital role in protecting life on Earth. It absorbs much of the Sun’s harmful rays but allows enough through to warm up the planet. It protects the planet from meteor showers. The atmosphere also holds oxygen and water, which are essential for life.

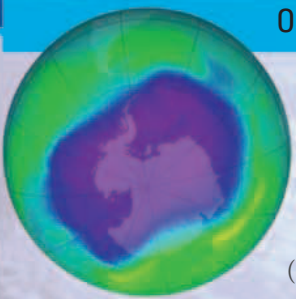
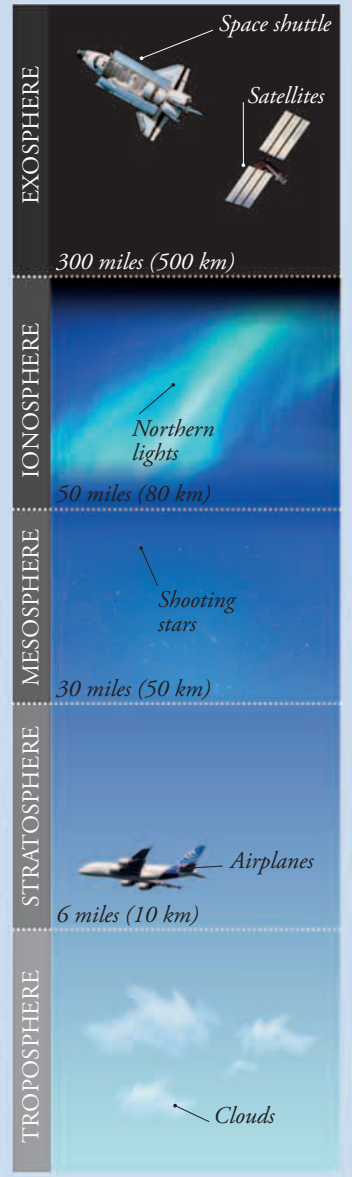


◀ **WHAT’S IN THE AIR?**  
*Around 20 percent of the atmosphere consists of oxygen, which we need to breathe. Most of the rest is nitrogen, but a tiny fraction is made up of other gases, such as carbon dioxide and methane.*



## TAKE A LOOK

The atmosphere consists of five layers—the troposphere, stratosphere, mesosphere, ionosphere, and exosphere.



## OZONE LAYER

- **Ozone forms** a thin layer around Earth, about 15 miles (25 km) above the surface.
- **The ozone layer** protects life from the harmful ultraviolet (UV) radiation in sunlight.
- **Harmful gases** in aerosols and other systems destroy ozone, creating holes in the ozone layer over the polar regions.

▲ **HOLE** A satellite image reveals the ozone hole (purple).

◀ **TIGHT SQUEEZE** Gravity squeezes 99 percent of the gases in the atmosphere into the first 25 miles (40 km) above Earth’s surface. The rest extends 600 miles (1,000 km) out into space.

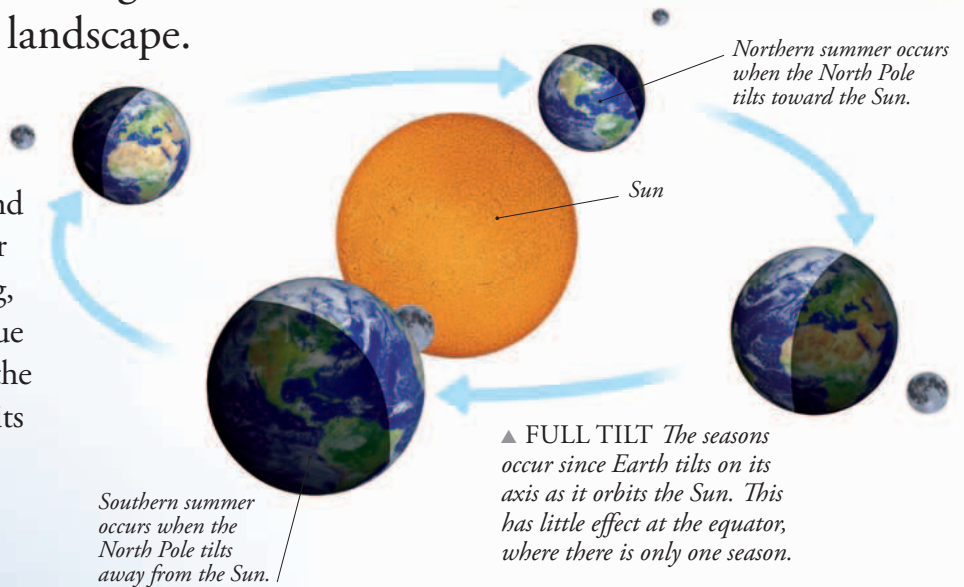


# Climate

The climate of a particular area is the different patterns of weather and temperature over time. Factors that influence climate include distance from the equator and the sea, height above sea level, and the surrounding landscape.

## SEASONS

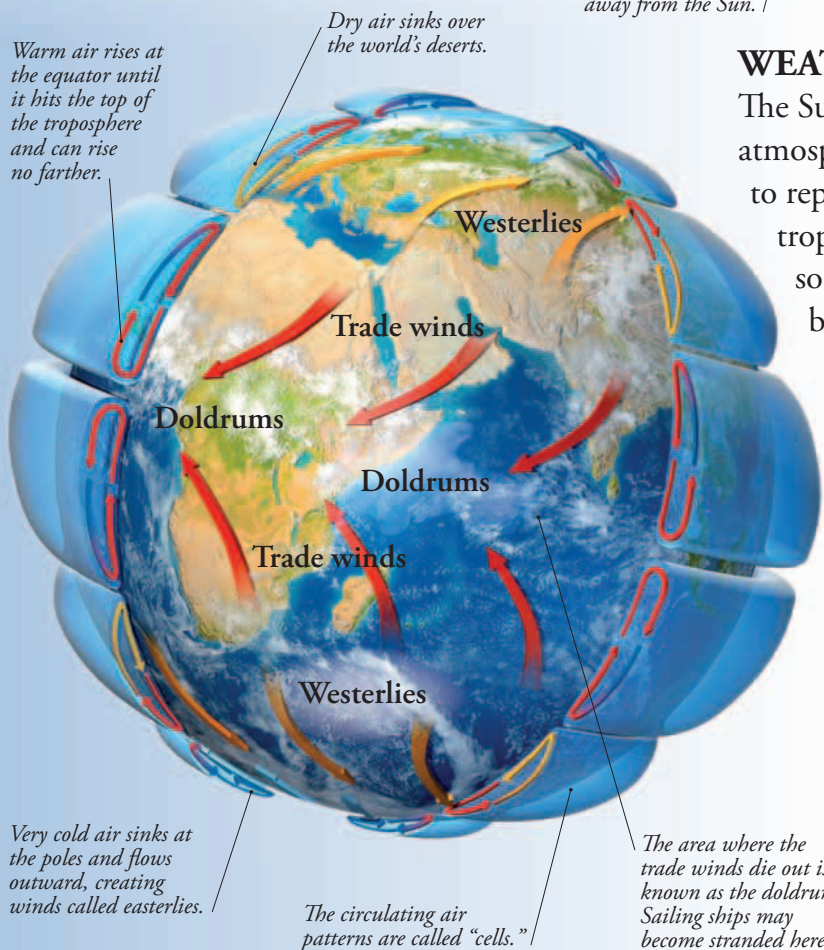
The seasons are annual changes in climate that occur in the northern and southern hemispheres. There are four seasons in temperate regions—spring, summer, fall, and winter. They are due to the differences in day length and the strength of the sunlight as Earth orbits the Sun. In many tropical and subtropical areas, there are two seasons—dry and wet.



**FAST FACTS**

- For the last 50 years, the average temperature on Earth has been increasing by about  $\frac{1}{8}$  of a degree every ten years. This is known as global warming (👁️ p. 78–79).
- The change in temperature is causing the glaciers and ice caps to melt.

EARTH



## WEATHER MACHINE

The Sun heats Earth's surface, which warms the atmosphere. Warm air rises, and cool air moves in to replace it, causing winds. Warm air rises in the tropics. Cool air moves in from the north and south. Since Earth rotates on its axis, the winds bend, creating huge swirling weather patterns.



◀ **TEMPERATE** This zone experiences changes in temperature and rainfall during the year, but none are too extreme.



◀ **POLAR** The Arctic and Antarctic polar regions experience freezing conditions and little rainfall.



◀ **TROPICAL** This zone lies north and south of the equator and is generally hot and humid.

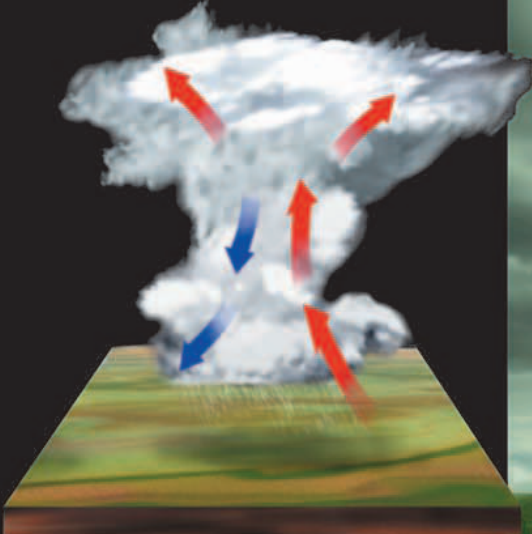


# Extreme weather

These days we can watch the weather from space and even forecast it, but the one thing we cannot do is control it. Weather is one of the great powers on our Earth and in its extreme form is an awesome, deadly natural force.

## HURRICANE

Also known as cyclones and typhoons, these enormous swirling storms rip away buildings and wash away roads. In 2005, the 175 mph (280 km/h) winds of Hurricane Katrina caused catastrophic flooding in New Orleans, Louisiana, killing over 1,500 people.



▲ **THUNDERSTORMS** Huge storms form when warm air rises and cools, causing huge clouds to grow higher and higher. As the water vapor cools, it falls down as heavy rain.



▲ **LIGHTNING** High up in a thunder cloud icy raindrops collide and create an electric charge. The bottom of the cloud is negatively charged and the top is positive. Electricity jumps between the two and that's lightning.



▲ **FLOOD** Flooding causes more damage and kills more people than any other catastrophe caused by extreme weather. In 1997, more than 250,000 people were driven from their homes in Bangladesh.



## PREDICTING WEATHER

Weather can be very unpredictable, but most of the time forecasts warn us of extreme weather and can help save lives. Weather satellites orbit the Earth continuously, taking photographs. There are about 10,000 weather stations all over the world, on land and at sea, gathering data on clouds, temperature, air pressure, wind direction and speed, and so on. They pass the information to huge computers, allowing meteorologists to predict how the weather will change.

## FAST FACTS

- There are about 2,000 thunderstorms happening in the world right now.
- Lightning kills 100 people every year.
- Australia suffers from about 15,000 bushfires each year.
- Arica, Chile, is one of the driest places on Earth. From 1903 to 1918 it had no rain.
- A tidal wave, or tsunami, hit Indian Ocean shorelines in 2004. It killed an estimated 230,000 people (👁️ p. 35).



▲ FIRE *All it takes is dry, parched earth and a bolt of lightning for a devastating forest fire to rage across miles and miles of land. If a fire hits urban areas it can destroy homes and claim many lives.*



▲ SNOW *A snowstorm can be lots of fun but can also be deadly. A blizzard can bury cars and even houses. In 1999, a heavy snowfall caused an avalanche and buried the town of Galtür, Austria, under 33 ft (10 m) of snow.*

## ▶ HAILSTONES

*Hail forms inside huge cumulonimbus clouds and often falls during a storm. Most of the time hailstones are no bigger than marbles, but in June 2003 a hailstone measuring 7 in (17.8 cm) wide fell in the United States. That's the size of a soccer ball!*

## ◀ TORNADO A

*tornado is a whirling funnel of air that moves across the ground and destroys everything in its way. The United States suffers from more tornadoes than any other country.*

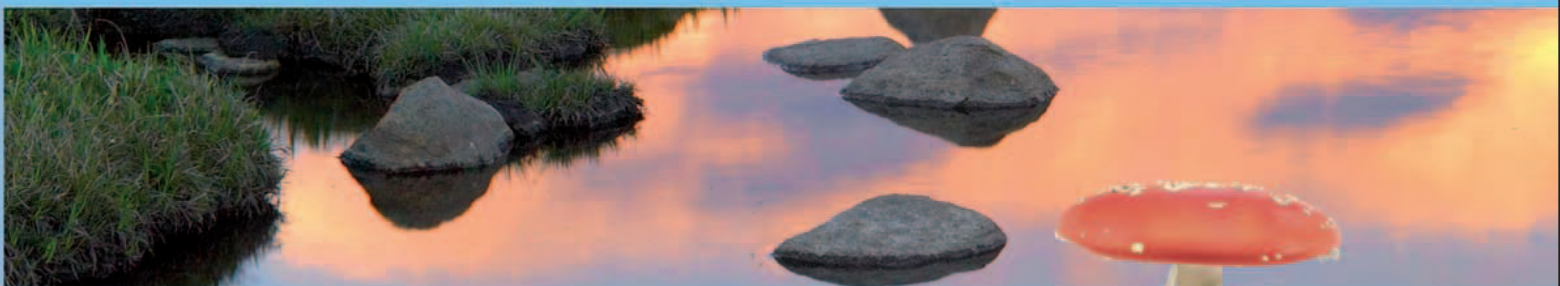




# ENVIRONMENT AND ECOLOGY



- Only simple organisms, such as algae, can survive in the Dead Sea since it is so salty.
- Bacteria live in the mud of the Mariana Trench,  $\frac{3}{4}$  miles (11 km) under the sea.
- Tropical rain forests get more than 70 in (180 cm) of rain a year.
- Antarctica is the driest and coldest desert in the world.
- Grassland covers more than half of Earth's land surface, but most is used for farming.



What is the greatest threat to Australia's **coral reef**?

*Find out on pages 76–77*



What important role do **fungi** play in a forest?

*Find out on pages 66–67*







*Definition:* **Environment** is the natural surroundings or conditions in which a plant, organism, or animal is found. **Ecology** is the study of species in their environment.

- Only 3 percent of the world's water is fresh water. More than 65 percent of this is ice.
- The volume of water in the Pacific Ocean is the same size as the Moon.
- The biggest hot desert is the Sahara. It covers one-third of the area of Africa.
- The Aral Sea has almost dried up because the rivers that supply it have been diverted.
- Eighty percent of forests have been cut down by humans in the past 10,000 years.



How do **cacti** survive in the desert without water?  
*Find out on pages 62–63*



Why do **zebras** prefer to live in herds?  
*Find out on pages 64–65*





## WHAT IS ECOLOGY?

■ Ecology is the study of the relationships between animals and plants and the environment they live in. Ecologists divide the world up into a series of environmental regions called biomes, which are based on climate and inhabited by similar types of animal and plant. Within these biomes are smaller areas called ecosystems, which have their own groups of animal and plant that have adapted to the particular conditions found there.

# A shared planet

Humans are not the only species on the planet. We share it with at least 1.6 million other types of animal and plant. The way that living things interact is highly complex, but vital for survival.

## LIVING WORLD

There are very few places on Earth where life does not exist. Even extreme places, such as the icy poles or hot volcanoes, are populated by organisms. Scientists describe the whole of the living world as the biosphere.

### JUST THE JOB

Animals and plants have adopted different strategies to survive in their environments. Some have specialized to live in one particular habitat, others can survive in many. Often, they have changed physically or adapted their lifestyles to suit the conditions.

**Habitat** Thorny devils change the color of their skin when they are cold or alarmed.



**Migration** Some birds and animals travel great distances every year to find food or to breed.



**Population** The number of lemmings changes according to food availability.





**FOOD CHAINS**

All animals eat other living things to get the nutrients they need for energy and to build their bodies. This energy starts with sunlight, which is used by plants and phytoplankton. This is the start of a food chain, where energy is transferred from plants to a series of bigger and more predatory animals.

▼ **SUN** *The energy that shines down from the Sun is absorbed by phytoplankton.*

▼ **KRILL** *Billions of these shrimplike creatures feed on plankton in the cold polar seas.*

▼ **COD** *Fish eat krill and plankton in the upper layers of the ocean.*

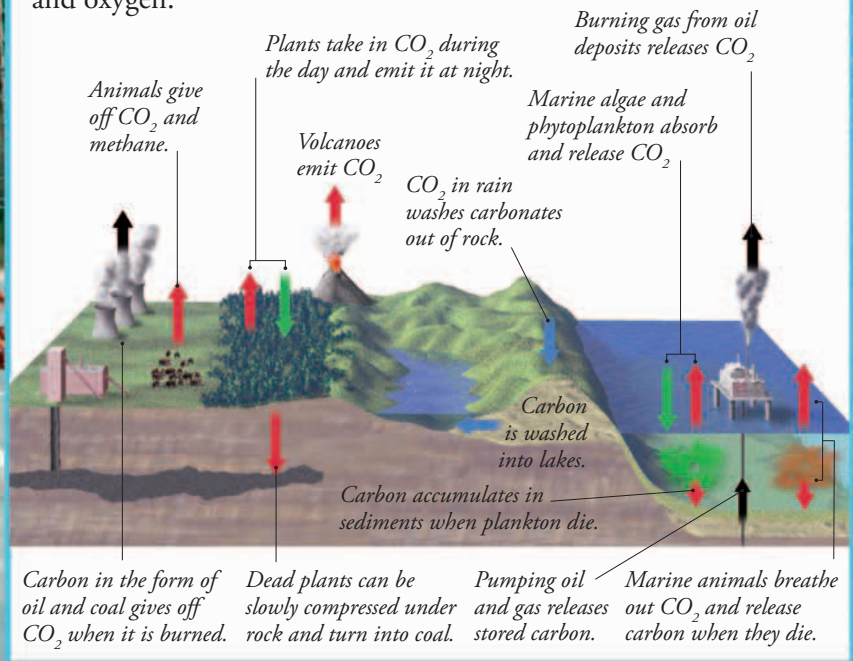
▼ **SEAL** *Hungry seals chase schools of fish, such as herring and young cod.*

▼ **KILLER WHALE** *These large predatory mammals eat seals.*



**THE CARBON CYCLE**

Carbon is a vital element to all life on Earth. Its atoms move in a natural cycle between land, water, and the atmosphere. Animals and plants are part of that cycle. Many systems on Earth work in a similar way, recycling vital ingredients such as nutrients, water, and oxygen.



▲ THE CRABS of Christmas Island will cross roads, tennis courts, and golf courses to get to the sea during the breeding season.

**Lifestyle** Pandas are only found in small areas of China where their main food, bamboo, grows.



**Numbers** Small plants grow quickly and produce lots of seeds so they have more chance of survival.



**Cooperation** Many plants need insects to pollinate them. The insect benefits from their nectar.



**Dominance** Trees put more effort into growing tall so they can get more light and nutrients than other plants.





# Habitats

All living things need a place where they can live and breed successfully. This place is called a habitat. Habitats can be as big as a prairie or as small as a puddle. There can be many different habitats in a single area of land or sea.



**A home of their own** Every animal and plant needs particular conditions for it to thrive. Plants need the right temperature, rainfall, and soil to grow in. Animals need shelter, food, and space to roam around. An organism will often adapt its lifestyle or even how it looks and behaves to suit its surroundings. This process is called evolution.

## FRAGMENTATION OF HABITAT



Fragmentation happens when land is cleared for farming or other uses, so the original habitat is broken up. The creatures that lived there are left with small islands of habitat that leave them vulnerable to predators because there is less cover when they search for food. Conditions important to plants, such as light or wind levels, may also change significantly.



**Mountains** Near cold and rocky mountaintops animals need a warm coat and nimble feet to survive.



**Forests** These are home to a wide variety of plants and animals that live at different levels among the trees.



**Coasts** Animals that live here have to cope with the sea coming in and out twice a day and constant battering by waves.



**Mangroves** The roots of mangrove trees are surrounded by salty water, but they make good hiding places for fish.



**Coral reefs** Reefs provide homes for hundreds of species. They are created by the skeletons of small marine animals.



## BIOMES OF THE WORLD

Ecologists group similar types of ecosystem into areas called biomes. Each type of biome, such as a tropical rain forest, has the same sort of climate and habitat as other rain forests around the world, but the species it contains may be different. Hot, wet, tropical biomes have many more species than cold or dry ones.



The northern hemisphere has a wide range of biomes, but those lying on the equator have a greater diversity of species.



**Evolution** Every part of the world has species that do not live anywhere else. These are called native species and have evolved to suit the local conditions. These tree ferns only grow wild in New Zealand.

**Invasers** When new species are introduced to an area they can have a devastating effect on the ecosystem. Cane toads (right) were brought in to eat beetles in Australian sugar fields, but became pests as they also eat other animals.



ENVIRONMENT AND ECOLOGY

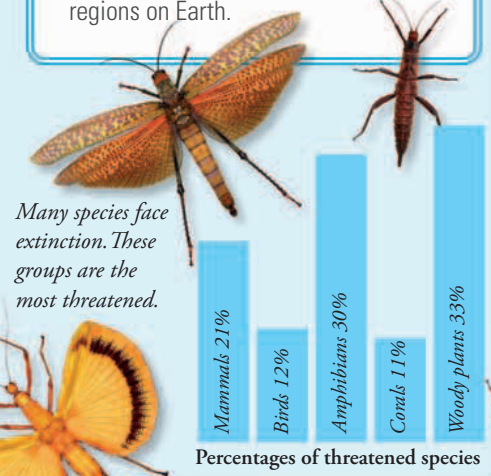
## BIODIVERSITY



Biodiversity is a measure of the variety of species in an ecosystem. All species have a role to play in the ecosystem. To understand an ecosystem properly, scientists have to identify all the organisms living there and find out how they interact. These researchers are collecting moths. Then they can protect any species or groups of species that are important to that ecosystem.

**FAST FACTS**

- Nearly 1.65 million species of plant and animal are known to exist.
- Almost 1 million of those species are insects.
- More amphibians face extinction than any other animal group.
- About 5,000 new species are discovered every year, mostly insects.
- Rain forests are the most biodiverse regions on Earth.



Many species face extinction. These groups are the most threatened.



## TELL ME MORE...

The Saguaro cactus is one of the tallest in the world—it can grow as high as 40 ft (12 m) and live for up to 200 years. Only found in Arizona, California, and northern Mexico, it needs more water than some cacti, but it's fairly tolerant of frost.

# Deserts

We think of deserts as being hot, but some of them are very cold. What deserts **ARE** is dry. Any place that gets less than 10 in (25 cm) of rain or snow per year (such as the Antarctic ice sheet) is a desert.

**This is the Sonoran Desert** in the southwestern United States.

## WARM DESERTS

The thing about hot deserts is that they're hot all the time—cold deserts can be frosty in winter and boiling in summer. There is not much moisture, so there are very few clouds. At night, with no cloud “blanket,” the temperature can drop dramatically.

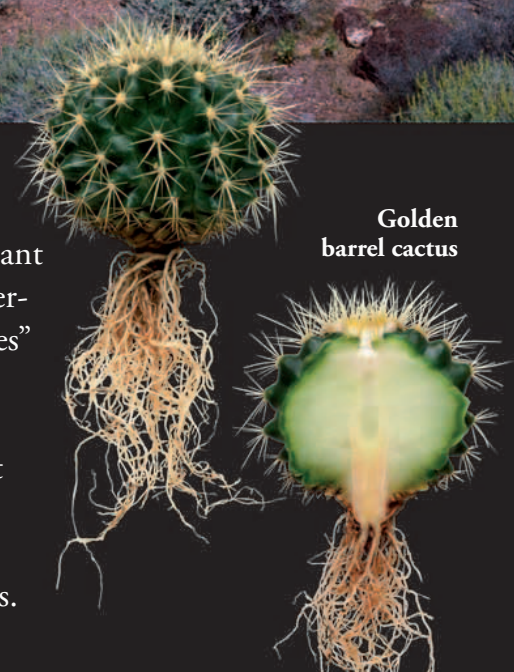


## DESERT IN BLOOM

Once in a while, there is a rare and precious shower of rain, and the desert bursts into bloom. (See above, Anza-Borrego State Park, California.) This is because seeds lie dormant—sometimes for years. When water falls, they germinate, flower, and create new seeds.

## CACTI—FIT FOR PURPOSE

The “body” of a cactus plant is actually a swollen, water-storing stem. The “prickles” are a kind of leaf that allows very little water to evaporate. In some desert plants, it's the leaves that swell and store water—these are called succulents.



Golden barrel cactus





## LOOK CLOSER: DESERT FEATURES

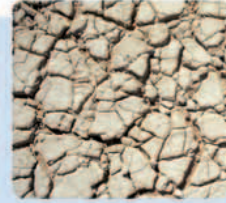
■ Deserts have formed in many different landscapes, wherever water is in short supply. Because there aren't many plants on the surface, deserts are vulnerable to weathering and erosion. Also, the huge variation in temperature can cause massive rocks to crack.



▲ **DUNES** form large "sand seas" called ergs. The wind sculpts their graceful shapes.



▲ **ARCHES** Erosion and sandstorms can puncture a rocky ridge to form an arch.



▲ **EARTH** Natural salts can cement rocks together into "desert pavement."



▲ **BUTTES** form when a plateau has been eroded to leave a flat hill with steep sides.

## COLD DESERTS

The coldest and most northern of all the world's deserts, the Gobi Desert (shown here) stretches across China and Mongolia. Like many cold deserts, it sits on a high plateau, where the temperature is naturally lower than at sea level.

## SANDSTORMS



Strong, dry winds blow across the desert, carrying clouds of sand that reduce visibility to almost zero. Roads and wells are often covered completely, and a violent storm can dehydrate—or even suffocate—animals and people. Sandstorms last for hours, and some can even go on for days.

## DESERT ANIMALS

From insects and reptiles to huge mammals, most desert animals have highly specialized characteristics that are precisely suited to their extreme conditions. Some get their water from the food they eat, for example, while others sleep during the hot days.



**FENNEC FOXES** use their huge ears to help them locate prey. The large surface area also allows heat to escape.



**JERBOAS** keep cool by sealing themselves in an underground den.



**THORNY DEVILS** have skin that absorbs water like blotting paper.



# Grasslands

Grasslands spring up in places that are too dry for forests to grow but get enough water to stop them from becoming deserts. Almost half of the Earth's land surface is covered by grasslands. They support a wide variety of animals, but the wide open spaces offer little protection from predators for larger animals.

## TROPICAL GRASSLANDS

Also called savannas, tropical grasslands have distinct wet and dry seasons. Although it is warm all year round, rain only falls for six to eight months of the year. During a drought the grass can catch fire, but this is good for regenerating the savanna.

### SAVANNA TREES

*The leaves and small branches of savanna trees provide important food for browsing animals such as giraffes.*

*CHEETAHS are perfectly camouflaged against the savanna grass.*

## TEMPERATE GRASSLANDS

Temperate grasslands (called prairies in North America) have hot summers and cold winters. Although they get rain throughout the year, there is too little for trees or shrubs to survive. However, the rich soil is good for the hundreds of wild flower species that grow among the grasses.

### WILD BISON

*have been replaced by cattle as farmers have turned prairie into land for agricultural grazing and cereal crops.*



FACTFILE

- Elephant grass can grow to 26 ft (8 m) high—tall enough to hide an elephant!
- Cheetahs probably evolved in Asia. Until about 20,000 years ago, their relatives were commonplace in Europe, India, China, and North America, not just in Africa. They disappeared from many areas after the last ice age.
- The lack of trees mean that many birds have to build their nests in burrows.
- Grasslands are found on every continent except for Antarctica.

LIFE ON THE PLAIN

The huge quantities of grass out on the prairie support some of the worlds biggest herbivores, such as elephants, rhinos, and giraffes. It also offers a hiding place for smaller animals and cover for predators to stalk their victims.

Meerkat



**Burrowers** Many small animals live in burrows. These protect them from the hot sun and cold nights, and help them escape from predators. Some animals live in burrows dug by other species.



Aardvark



Prairie dogs



**Grazers** Most grazing animals live in large herds that offer protection from predators. They have long legs for running and strong teeth for chewing tough grass. Often they have to migrate to find fresh grass in the dry season.



Kangaroo



Bison



Zebra

**Predators** These rely on stealth to obtain food. They frequently hunt in packs to isolate an animal from a herd or to scare other predators from a kill.



Hyena



Wolf



Jackal

Lion



**TURKEY VULTURES** soar over the American prairies, sniffing the wind for dead animals to eat.

LOOK CLOSER: AMAZING GRASS

■ Grasses are one of the biggest families of flowering plant. They are well suited to dry conditions since they can store food in their roots. Because their leaves grow from below ground, grasses can survive being nibbled by animals as long as their roots are not disturbed. Their tiny flowers are pollinated by the wind rather than insects.



▲ **FOXTAILS** These grasses have spiked seeds that attach to passing animals for dispersal.



▲ **BUFFALO GRASS** This short, hardy grass is found on the plains of North America.



▲ **SPINIFEX** Properly known as *Triodia*, this hummock grass covers the Australian bush.



▲ **WHEAT** Cereal crops were originally wild grasses cultivated for food by humans.



# Forests

Trees are the biggest plants on the planet. Forests of them cover large areas of land and provide shelter for other plants and animals. They will flourish anywhere that is warm and wet enough during their growing season.

## TELL ME MORE...

The Amazon rain forest in South America covers an area almost as big as Australia. An area of 2.5 acres (1 hectare) may contain more than 750 types of tree and 1,500 other plants. Almost a sixth of all flowering plants and one-seventh of all bird species live there. The trees keep their leaves all year long.

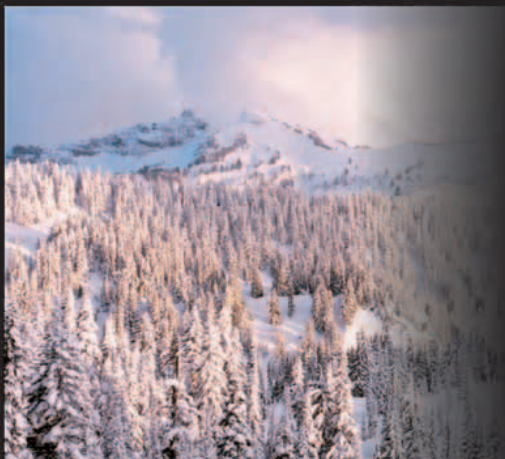
### RAIN FOREST

There are two types of rain forest—temperate and tropical. Both are found in areas of very high rainfall, which helps the trees grow tall and fast. Rain forests are full of animals and plants. In fact, about half of all species on the planet live in rain forests. Despite all the plant material, the soils in these regions are thin and poor in nutrients.



### BOREAL FOREST

Boreal forests are found in northern countries that have long, snowy winters. Most of the trees that grow here are conifers, such as pine, spruce, and larch. Instead of flat leaves they have thin needles that help them save water and resist strong winds. Their branches slope downward so that snow slides off.



▼ DYING LEAVES  
turn brown in  
the fall.



▲ LEAVES fall from deciduous trees in the fall when light levels and the temperature drop. This allows trees to save energy and conserve water over the winter.

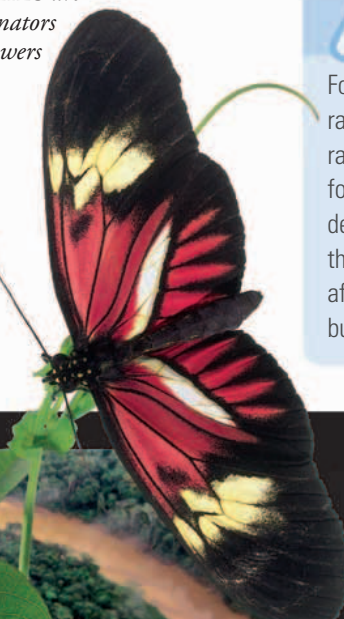
### TEMPERATE FOREST

Mixed, mainly broadleaf woodlands grow in regions that have long, warm summers and cool, frosty winters. They drop their leaves in winter, which allows flowering plants such as bluebells and aconites to grow in early spring before it gets too shady. The leaves break down to form a deep, rich soil. Many of these forests have been cleared for farming.





▼ BUTTERFLIES are important pollinators of rain forest flowers high up in the canopy. The caterpillars of this postman butterfly feed on passion flower vine leaves.

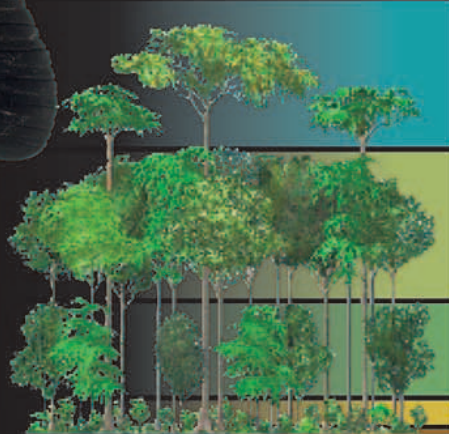


UNDER THREAT: DEFORESTATION

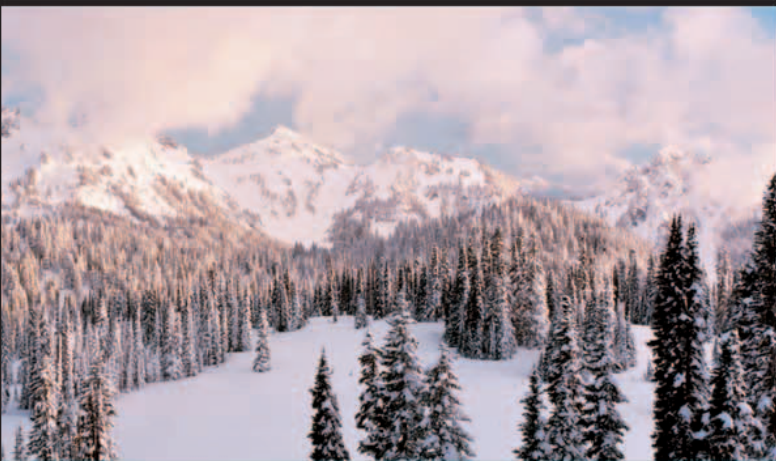
Forests face a number of threats. Large areas of the Amazon rain forest are being cleared to provide land for cattle ranching and soybean production. Other forests are logged for their valuable timber or for fuel. This can have a devastating effect on the forest ecosystem. Animals lose their homes and food supply, and the changing conditions affect plant growth. Some forests are planted to produce wood, but these lack much of the native wildlife of natural forest.



RAIN FOREST LAYERS



- EMERGENTS—the tallest trees are home to butterflies, eagles, and bats.
- CANOPY—this layer is full of animals, birds, climbing plants, and orchids.
- UNDERSTORY—provides homes for snakes and lizards and cover for predators.
- SHRUB LAYER—consists of saplings and broad-leaved shrubs.
- FOREST FLOOR—receives little light and is covered in decaying plant material.



▼ CONIFERS protect their seeds in cones.



Cone  
Seeds



▲ SQUIRRELS are experts at breaking open cones. Their sharp teeth can gnaw through the woody casing to expose the seeds.



◀ FUNGI are useful in forests. They break down rotting trees and leaves and provide food for animals and insects.



# Mountains

No other place on Earth shows such a dramatic variation in habitats as you can find on the slopes of a mountain. The warm, sheltered valleys abound with animal and plant life, but freezing winds batter the exposed peaks. Only the hardiest of species can survive in this extreme environment.

## RICH RESOURCES

Almost 25 percent of the Earth's land surface area is covered by mountains. They feed most of the world's river systems and are rich in mineral resources. Few people live high up in the mountains, but many use them for activities such as climbing and skiing.

### MOUNTAIN HIGHS AND LOWS

- Standing at a height of 29,029 ft (8,848 m), Mount Everest is the tallest mountain on the land. It is part of the enormous range called the Himalayas in Central Asia.
- Mauna Kea, in Hawaii, is the world's highest mountain, rising up 33,474 ft (10,203 m) from the ocean floor. Only 13,796 ft (4,205 m) is visible above sea level.
- Oxygen levels drop sharply with increasing altitude. Many animals produce more red blood cells, or have larger hearts, to carry more oxygen around their bodies.
- A "dead zone" occurs above 20,000 ft (6,000 m). Few animals can survive in the dead zone due to the high winds and freezing temperatures.
- The Himalayan pika lives at an altitude of 16,800 ft (5,250 m)—the highest of any known mammal in the world.



◀ **THE HIGH LIFE** *Hardy birds, such as the colorful ptarmigan, can withstand the harsh environment on the upper slopes of the mountain.*



◀ **FLOWER SLOPES** *Highland vegetation such as bell heather supports a range of herbivores, which, in turn, are food for predators such as the gray wolf.*



◀ **RIVER VALLEY** *Mountain streams trickle down through the valley floor, forming a rich habitat for bank voles and other animals.*





## TELL ME MORE...

Mountains contain a rich range of habitats. Lush alpine meadows give way to conifer forests, while the snow-capped peaks dominate above. The main reason for the variation is the sharp drop in temperature with altitude—about 11°F (6°C) for every  $\frac{3}{8}$  mile (1 km) in winter.

## MOUNTAIN MAMMALS

Despite the rugged terrain and cold air, many mammals make their homes in the mountains. They must adapt to survive, so many grow thick winter coats to keep warm. Others migrate up and down the slopes through the year to avoid the worst weather.



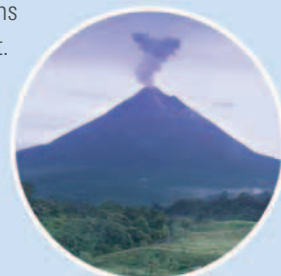
▲ MOUNTAIN GOAT *Thick winter coats protect these agile, muscular herbivores as they scramble up steep mountain slopes.*



▲ SNOW LEOPARD *The predatory snow leopard has thick fur and small, rounded ears to conserve body heat.*

## BUILDING MOUNTAINS

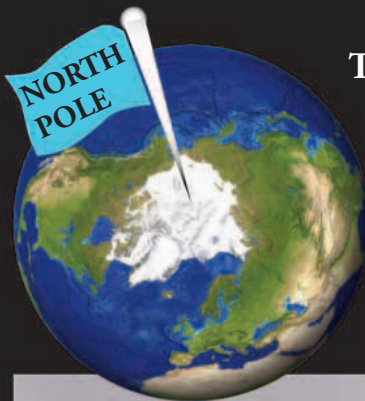
Mountains form when vast sheets of rock, called tectonic plates, collide beneath the Earth's surface. Depending on which plates collide, the land is either pushed up to form mountains or molten rock rises to the surface to form volcanoes (👁️ p. 32–33, p. 34–35). Volcanoes are more regularly shaped than mountains that have been folded and bent. Mountains tend to have poor, rocky soils and little grows near their peaks. Despite the danger of volcanoes, their ash turns into fertile soil for growing crops.





# Polar regions

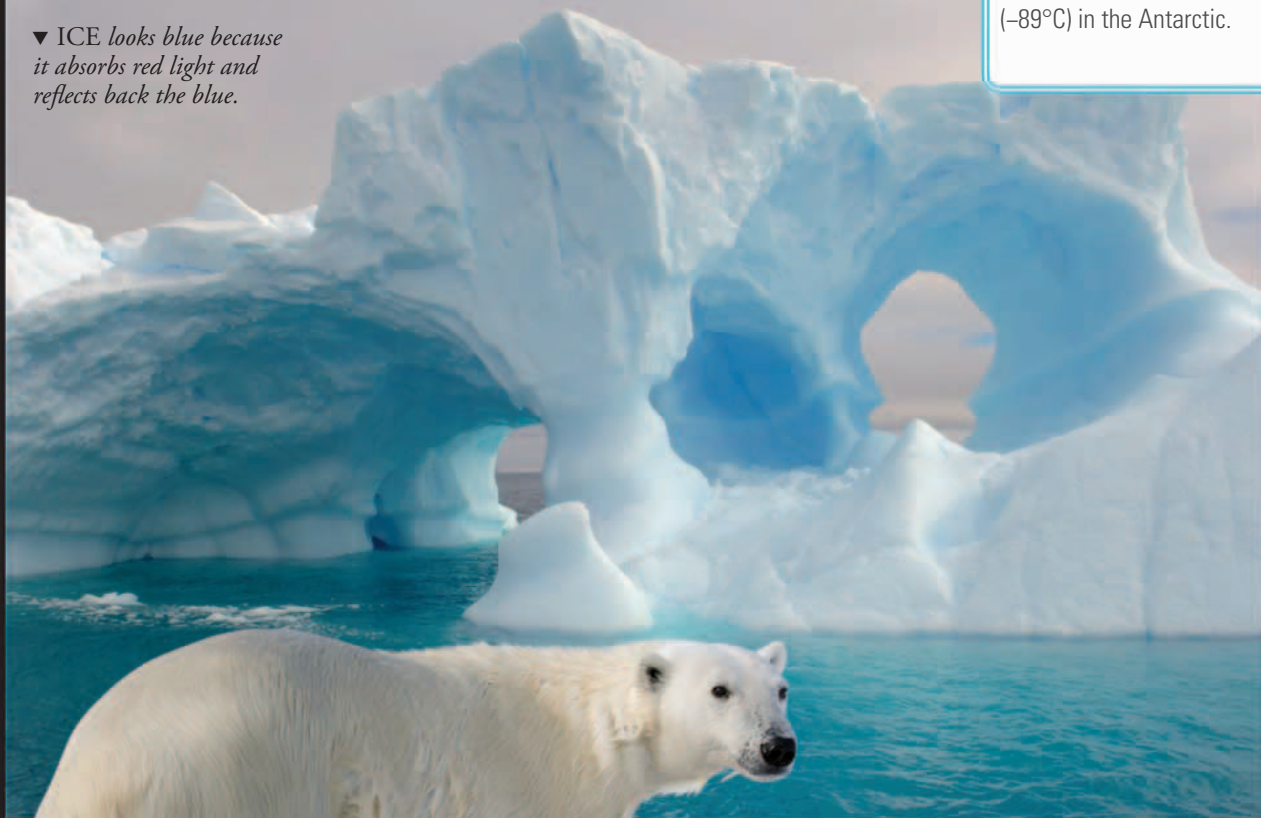
Imagine living in a place where for six months of the year, there is no day, and the other six months, there is no night. Add to this freezing cold temperatures and you have two of the most inhospitable places on Earth—the North and South poles. Surprisingly, they are teeming with life.



## THE ARCTIC

The Arctic is a huge raft of floating ice surrounded by land. At the North Pole the ice remains frozen all year, but farther south the ice breaks up and melts in the summer. There are concerns that climate change may melt the sea ice permanently.

▼ ICE looks blue because it absorbs red light and reflects back the blue.



## FAST FACTS

- The Arctic Ocean is the smallest and shallowest of the five major oceans.
- Antarctica is covered by 90 percent of the world's ice to an average depth of 1 mile (1.6 km).
- There are more than 70 lakes under the Antarctic ice sheet.
- The coldest recorded polar temperatures are  $-90^{\circ}\text{F}$  ( $-68^{\circ}\text{C}$ ) in the Arctic and  $-129^{\circ}\text{F}$  ( $-89^{\circ}\text{C}$ ) in the Antarctic.

## Walking on top of the world

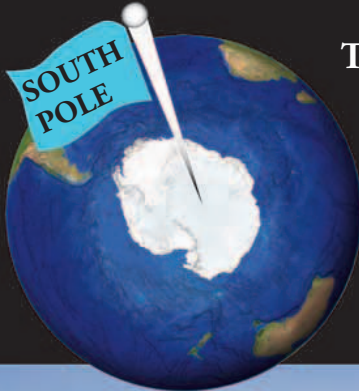
More animals live in the Arctic than Antarctica. This is because the winter ice provides a bridge to Russia and North America and more varied food sources. Land predators, including polar bears and humans, also take advantage of the seals and fish that live beneath the ice.





## HUMAN INFLUENCES

■ People have lived in the Arctic for thousands of years. Native peoples, such as the Inuit and Yupik, have learned to survive the cold and live on a diet of mainly fish and meat. However, there is oil beneath the surface of the Arctic and Antarctica, which makes them a target for prospectors. Antarctica is protected from exploitation by treaty, but the shrinking ice of the Arctic is opening it up for exploration. Oil and gas pipelines already cross Alaska and Siberia, which has led to oil spills and environmental damage.



## THE ANTARCTIC

The Antarctic differs from the Arctic because there is land beneath the ice. Nothing lives in the interior, and it is classed as a cold desert because it is so dry. Freezing winds help make it the coldest place on Earth.

## THE TUNDRA

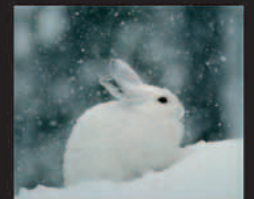
Tundra is the name given to cold, windy regions where the soil is frozen most of the year. The plants that grow here are low and stunted, but mosses, lichens, and small shrubs can survive the freezing conditions.



▼ CARIBOU *scrape away snow in search of lichen and moss.*



**Migration** Every summer huge herds of elk and caribou cross the tundra in search of food. Arctic foxes and hares stay all year.



### A safe refuge

There are no predatory land mammals on Antarctica, which makes it an ideal place for colonies of seals, penguins, and seabirds to breed. Despite it being so cold, the water is full of plankton, krill, and fish to feed their young.

**Winter coats** Some animals that live on the tundra change their coat from brown to white to hide them when it snows.



# Fresh water

Fresh water covers less than one percent of the Earth's surface. Falling rain flows back to the ocean in streams and rivers, or gathers to form ponds, lakes, and wetlands.

## Freshwater habitats

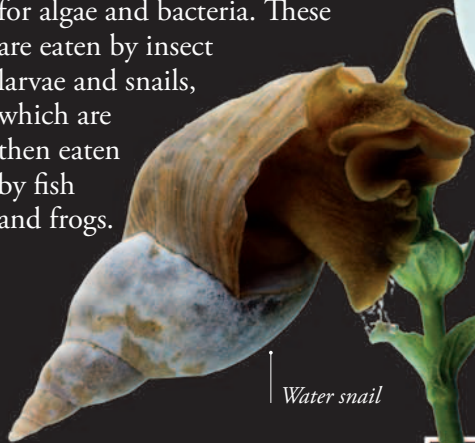
The creatures that live in freshwater habitats face many challenges. There might be flooding or the water can shrink to almost nothing, silt up with mud, or be choked by pollutants. Many animals have adaptations that help them cope. Salmon (right) spend part of their lives at sea and have a special mechanism that allows them to change from fresh to salt water and back again when they return to their home river to breed.

## Food chains

Food chains in rivers depend on inputs from the land around. This can be nutrients from farmland or fallen leaves, which provide food for algae and bacteria. These are eaten by insect larvae and snails, which are then eaten by fish and frogs.



▲ POND LIFE  
*A sample of water from a pond shows how many species live there, such as insects, snails, tadpoles, and pond weed.*



Water snail

## FISH HAVENS

Nearly 40 percent of fish species live in fresh water. Many fresh waters contain unique species, such as this African cichlid, because rivers and lakes rarely connect for species to colonize new areas.



## TAKE A LOOK: LIFE OF A RIVER



▲ SOURCE *Rivers start out as fast-flowing streams.*



▲ MOUTH *When they reach the sea, rivers are slow and wide.*

■ The ecology of a river changes as it runs from the hills to the sea. At its source, the water is too fast for plants to take root, but invertebrates and fish thrive in the well-oxygenated conditions. As it slows, a wider variety of plants take root in mud brought down from the hills. Animals make homes and hunt along its banks.



# Wetlands

Wetlands are among the richest habitats on Earth. They include permanently wet swamps and marshes, and bogs and fens that have waterlogged soils. The water can be fresh or salty.

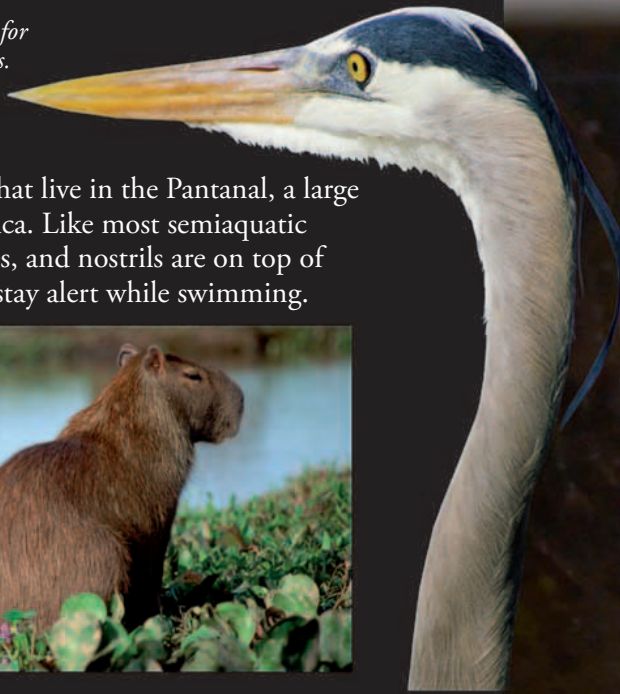
## WATERY ROOTS

Wetland plants have adapted to cope with the wet conditions. Many can float, or have waxy leaves that resist water. Their leaves also transport oxygen to submerged roots to keep them alive. Some roots can survive being exposed to the air or changes from fresh to salt water.

► HERONS stalk wetlands for fish hiding among plant roots.

## Swimmers

Capybaras are rodents that live in the Pantanal, a large wetland in South America. Like most semiaquatic mammals their ears, eyes, and nostrils are on top of their heads so they can stay alert while swimming.



**WOW!**  
Archerfish (below) live in mangrove swamps around Indonesia. They prey on insects that land on the leaves and roots of mangrove trees. After selecting a target from under the water, the fish sticks its snout out and blasts the insect with a jet of water. The insect falls into the water and is gobbled up by the fish.

ENVIRONMENT  
AND ECOLOGY



## TAKE A LOOK: WETLAND LIFE



■ Wetlands are home to many species of insect, amphibian, and reptile that need water to feed or reproduce in. This in turn attracts hungry birds and larger animals that prey on them. Many mammals have also adapted to wetland life, including beavers, hippos, and water buffalo.



▲ PITCHER PLANTS *These trap insects to obtain nutrients they can't get from the soil.*



▲ MAMMALS *The Okavango Delta in Africa is an ideal home for water-loving hippos.*



▲ REPTILES *Caimans and alligators are the chief predators in many swamps.*



▲ BIRDS *Still, wetland waters make ideal fishing grounds for waterbirds.*



# Oceans and sea life

Not only do oceans cover more than 70 percent of the Earth's surface, but they're also incredibly deep—easily the biggest habitat on the planet. What's more, they offer their residents a fairly stable temperature—and plenty of water!

**WOW!**

The biggest fish in the ocean is the whale shark. This monster can grow up to 60 feet (18 m) long—bigger than a bus!



## TAKE A LOOK: INGENIOUS FEEDERS

■ Earth's oceans accommodate a wide variety of exotic creatures. Many of these have developed unique adaptations that allow them to search for food and devour prey in their watery environment.



▲ **SQUID** grab prey using the suckers at the ends of their two long tentacles.



## OCEAN LAYERS

## ZONES AND HABITATS

In fact, the ocean is not just one habitat, but many. The first few feet (1 m) from the top—the surface layer—is the richest in both nutrients and vital gases from the atmosphere. But the surface layer is also vulnerable to pollution and floating litter, which can damage ocean life. Below this lie five more layers:



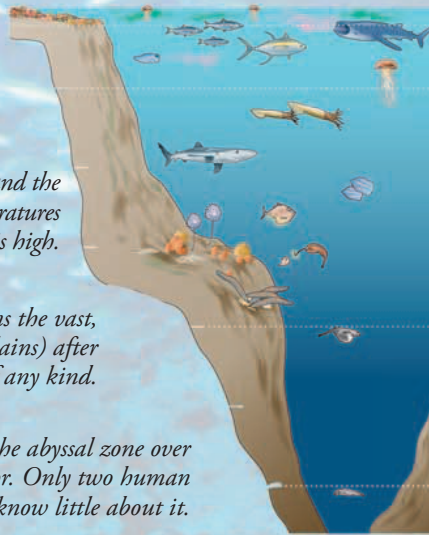
**THE SUNLIT ZONE** gets enough sunlight for photosynthesis to take place. If the water is clear, it can extend to 650 ft (200 m), but it's often much shallower. The base of all food chains is here.

**THE TWILIGHT ZONE** gets just enough light so that ocean creatures can hunt, but not enough for photosynthesis.

**THE DARK ZONE** gets virtually no light, and the only food is fallout or "snow" from above. Temperatures are low (35–39°F / 2–4°C), and pressure is high.

**THE ABYSSAL ZONE** contains the vast, muddy, seabed plains (abyssal plains) after which it's named, but very little life of any kind.

**THE HADAL ZONE** extends below the abyssal zone over less than two percent of the ocean floor. Only two human beings have ever been there, and we know little about it.



## COASTS

Coastlines provide many different habitats. High up on rocky shores, tough creatures such as barnacles survive crashing waves and exposure at low tide. In coastal mud, buried bivalves like clams filter food from the water.



▲ **ROCKPOOL** ecosystems contain algae and seaweed. Limpets feed on algae, and starfish feed on limpets, mussels, and other shellfish.

▼ **FISHING** is difficult to control because no one owns the open sea, and its vast waters are hard to police.

## MAN THE DESTROYER

Modern, intensive fishing boats can inflict serious harm on ocean ecosystems. Often, they take too many of one popular fish or scoop up endangered species unintentionally with their catch.

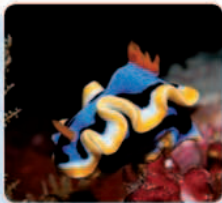


## BLACK SMOKERS

At hydrothermal vents, water heated under the sea dissolves minerals from the rocks. When it erupts through the ocean floor, it forms crusty "chimneys" that can reach several yards (meters) in height.



▲ **SEA ANEMONES** cling to rocks, and shoot at their prey with poison barbs.



▲ **SEA SLUGS** scrape algae off hard surfaces using small sharp teeth called denticles.



▲ **ANGLER FISH** use the dorsal spine on their heads like a fishing rod.





# Coral reefs

Sometimes called “rain forests of the sea,” coral reefs are spectacular marine ecosystems that thrive in warm, clear, shallow waters. Ecotourists love to visit the reefs to see the colorful and amazing variety of animals that live and hunt here.

**RICH PICKINGS**  
*Ocean predators such as dolphins (left) and sharks (right) lurk in coral reefs. They feed on the small creatures who live there.*

## FAST FACTS

- Corals are actually simple animals with tiny plantlike cells living inside them.
- The Great Barrier Reef, off northeastern Australia, is about 1,430 miles (2,300 km) long.
- Excess CO<sub>2</sub> in the atmosphere is making the ocean more acidic, which could damage coral.
- Fossil reefs have been discovered dating from more than 500 million years ago.

## THREATS TO CORAL

The reef is damaged by anchors scraping its surface and explosives thrown into the water to kill fish. Coastal developments release harmful sediment into the water, and stress, such as higher temperature, can cause coral to expel the algae in their body, so they turn white.

## TAKE A LOOK

- The main reef-forming organisms are known as hard or stony corals. Each one, called a coral polyp (right), secretes limestone from its gut cavity, and this builds up on the rock underneath. Some corals exist as single, large polyps, but most live in large colonies.

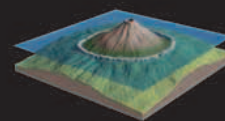


## ALL SHAPES AND SIZES

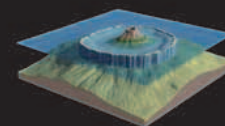
Coral reefs come in different forms. The most common is the **fringing reef** (such as this one in the Indo-Pacific Ocean), which grows off many tropical coasts. Corals can't grow above water, so the reef's flat top usually lies just below the surface. **Barrier reefs** grow parallel to a coastline, but farther out, while **atolls** (see right) form coral rings in the middle of the sea.

## BIRTH OF AN ATOLL

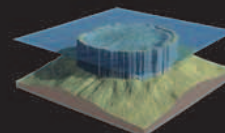
An atoll starts life as a fringing reef around a volcanic island. As the volcano weakens and sinks (or sea levels rise), the coral grows and turns into a barrier reef. Eventually, the volcano disappears, leaving an atoll—a ring of established coral reef around a central lagoon.



**1** Fringing reef forms around volcanic island.



**2** Barrier reef grows around sinking volcano.

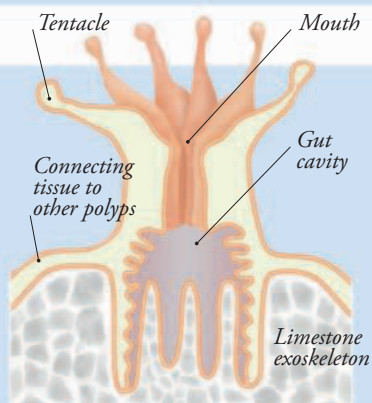


**3** Volcano disappears leaving atoll with central lagoon.

## CROWN OF THORNS

The world's largest starfish (it has a leg span of 12–16 in/30–40 cm), the crown of thorns feeds mainly on corals. Because of this, it can cause serious harm to coral reefs. The Great Barrier Reef off the coast of Australia, for example, has been severely

damaged by hungry crown of thorns. These prickly creatures hurt people, too—their spines are poisonous, so stepping on one can cause severe pain and sickness.



▲ **BRAIN CORAL** is arranged in wiggly lines that look like the surface of a brain.



▲ **FAN CORAL** feathers into delicate shapes and provides a home for tiny creatures.



▲ **STAGHORN coral** grows in the shape of branches, which look like tiny antlers.



▲ **SOFT CORALS** have tiny, individual polyps and can look like branching bushes.



# Climate change

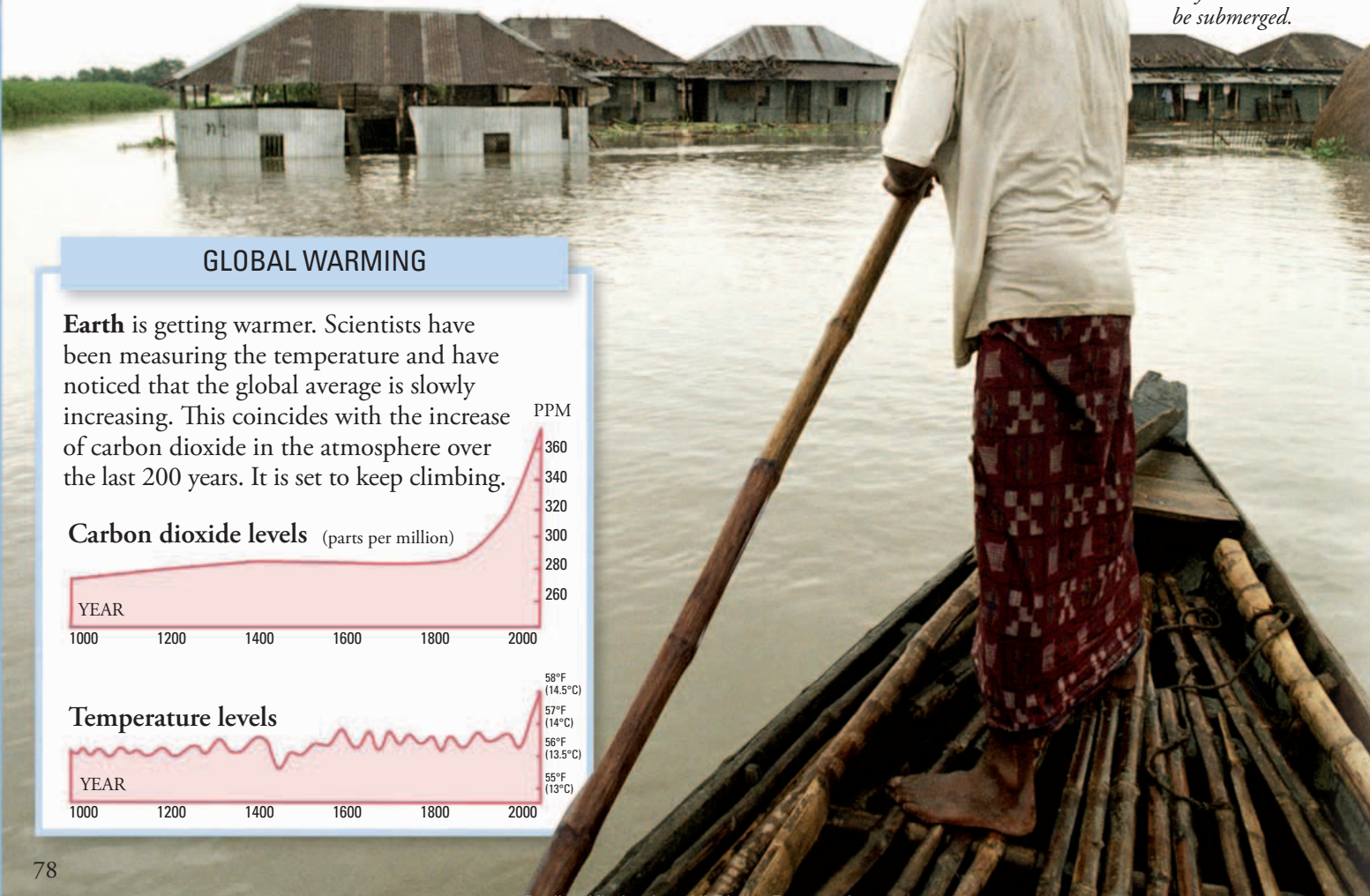
One of the biggest concerns facing our planet is the possibility of climate change. Although Earth has swung between extreme heat and cold throughout its existence, human activity, especially the burning of fossil fuels, may be interfering with the natural cycle and heating up the atmosphere.



## IMPACT OF CLIMATE CHANGE

Trying to predict what will happen as our planet warms up is not easy. We know that ice at the poles is melting and this is making sea levels rise. Warmer temperatures are likely to change other aspects of the weather. Some countries, such as those in North Africa, may become hotter and drier, while other areas such as Northern Europe, may become colder and wetter. There will probably be more intense storms, droughts, and flooding.

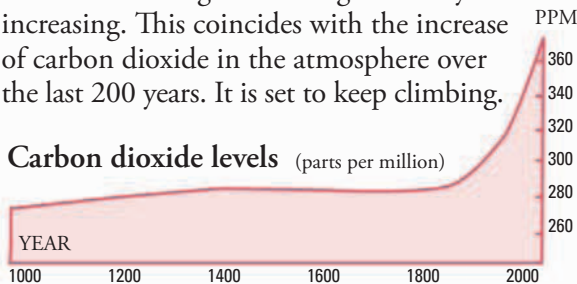
◀ *If global warming makes the glaciers melt, all the water locked in them will enter the sea. Sea levels will rise, and many areas will be submerged.*



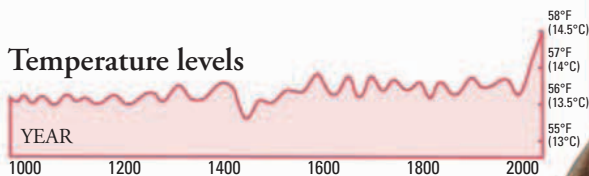
## GLOBAL WARMING

**Earth** is getting warmer. Scientists have been measuring the temperature and have noticed that the global average is slowly increasing. This coincides with the increase of carbon dioxide in the atmosphere over the last 200 years. It is set to keep climbing.

**Carbon dioxide levels** (parts per million)



**Temperature levels**





## GREENHOUSE GASES

■ The atmosphere helps keep the Earth warm. Gases such as water vapor, carbon dioxide, and methane trap heat from the Sun and keep the surface warm enough to support life. However, if these gases increase, Earth could turn into a giant greenhouse.

*Heat from the Sun enters the atmosphere. Some is reflected back from the surface, but most of it is trapped by the gases in the atmosphere.*



*Burning fossil fuels is adding more "greenhouse" gases to the atmosphere. If we add too much it could have a huge impact on the climate.*

### Beware of the burps!

One of the most worrying greenhouse gases is methane.

Huge quantities of it are produced in rice paddies and also by cows, which belch it out as a by-product of eating grass. Methane is 21 times better at warming Earth than carbon dioxide. Each cow can produce up to 53 gallons (200 liters) of methane a day—that's a lot of gas.



## UNDER THREAT

**Climate change** is not just a threat to humans. Many animals and plants will also suffer through changes to their environment. Reduced rainfall can be serious for trees, for example, or wetland habitats. The most vulnerable species are those that only live in one small area or are unable to move quickly. This includes some of the world's rarest species.

▶ *The Costa Rican golden toad is thought to have been driven to extinction by climate change, even though it lived on a nature reserve.*

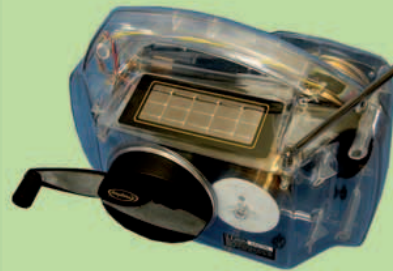


## SAVING ENERGY

Almost everything humans do in everyday life requires energy. Most of our energy comes from burning coal, gas, or oil, but these produce greenhouse gases. To prevent this from happening, scientists are looking at new ways to save energy and cleaner ways of making it.

**Preventative measures** We can all do our bit to prevent global warming by using energy saving devices, switching off lights, and turning the heating down a few degrees.

▼ *Wind-up radios save on batteries and electricity.*



▼ *Fluorescent bulbs use less energy than ordinary bulbs.*

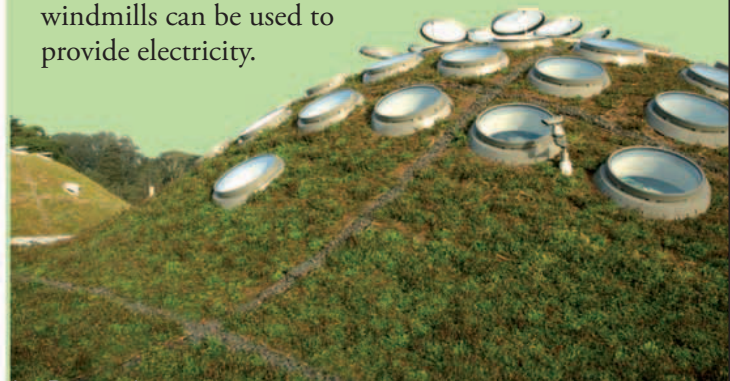


**Alternative fuels** Transportation is one of the biggest sources of greenhouse gases. Scientists are trying to develop new vehicles that use hydrogen, biofuels, and electricity instead of polluting gasoline.



◀ *This car runs on batteries that have been charged by electricity. It also has a solar panel in its roof.*

**Eco living** Houses can be built that need less energy to run them. This one is kept warm by the soil around it and is lit by special tubes that reflect and magnify sunlight. Solar panels and windmills can be used to provide electricity.





# Looking to the future

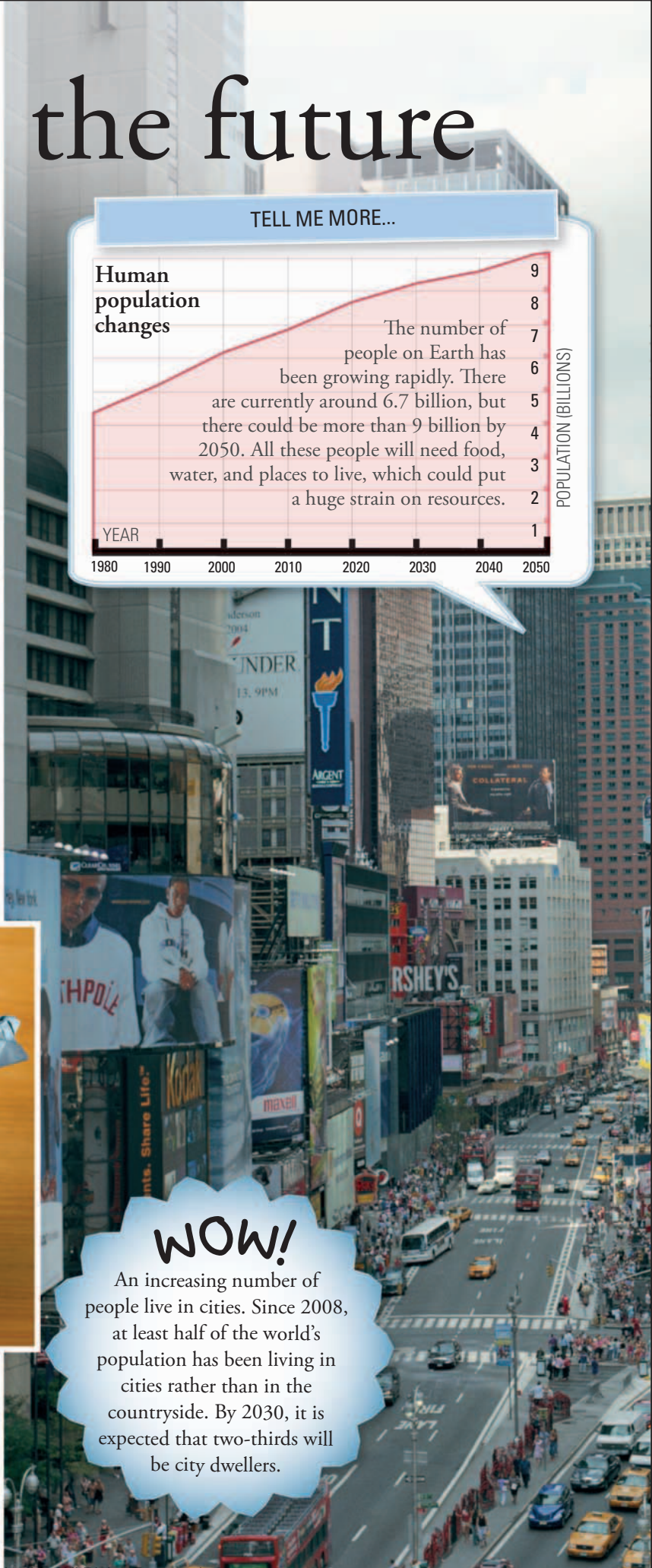
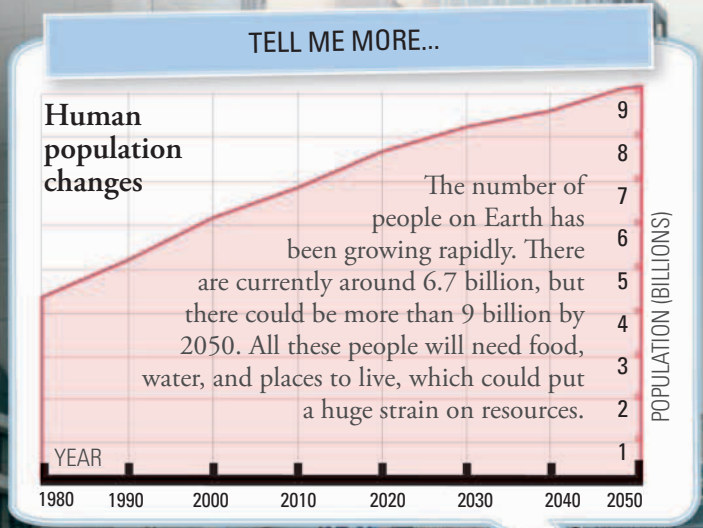
Humans are the dominant species on the planet. We make use of all of the Earth's resources, but there is a limit to how long these will last if we continue using them up at our current rate. It is in our own best interest to find ways of living that do not harm the environment and protect the animals and plants that live here, too.

## POLLUTION PREVENTION

For years, humans have been dumping the waste products of industrial processes on the ground, in rivers, or into the air. By using new and cleaner technologies we can reduce the amount of toxic substances produced and find ways to make them less damaging to the environment.



**Recycling** Humans use and waste an enormous amount of the Earth's resources. Most trash is put in large holes in the ground, but we are rapidly running out of space. A better way to save resources is recycling. Paper, plastics, metal, glass, and textiles can all be recycled and used again.



**WOW!**  
An increasing number of people live in cities. Since 2008, at least half of the world's population has been living in cities rather than in the countryside. By 2030, it is expected that two-thirds will be city dwellers.



**Earth** is getting warmer. Scientists have been measuring the temperature and have noticed that the global average is slowly increasing. This coincides with the increase of carbon dioxide in the atmosphere over the last 200 years. It is set to keep climbing.



**UNDER THREAT: PROTECTING SEEDS**

■ More than one-third of all flowering plants are vulnerable to extinction. Many of these species could be valuable to humans, but are being wiped out before their uses can be discovered. Scientists are now going around the world looking for plants and taking their seeds for storage in seed banks. This way, they can grow new plants if their original habitat is destroyed.



**CONSERVATION**

Wild areas are important, but many are being destroyed or raided for their resources. Organizations around the world are trying to protect wildlife and habitats by building sanctuaries for endangered species, such as the orangutan, and preserving key areas, including wetlands and forests.



**TAKE A LOOK**

Tourists bring wealth to an area. When wildlife itself is a tourist attraction, local businesses are likely to look after the habitat.

**Ecotourism** Traveling to a new place is fun, but tourism has an impact on the people, animals, and plants that live there. Ecotourism helps protect the future of national parks and other protected areas by encouraging operators to plan resorts in a way that looks after the local wildlife and environment.



**Reforestation** Many of the world's original forests have been cut down. Forests are a vital ecosystem, so in some areas new woodlands are being developed using native trees. If managed sustainably, they will provide an income for local people and a safe home for wildlife.






# LIVING WORLD

## KEY TO SYMBOLS

The following symbols are used in this chapter:


**Habitat** The type of place where the animal is typically found in the wild.


**Life span** The average maximum age of the species in the wild, which might be different from specimens kept in captivity. A question mark is used when there is no data available.

**Status** These triangles show if the animal is endangered, as listed on the IUCN Red List ( p. 85 for more information). A purple triangle shows there is not enough data to assess the animal.

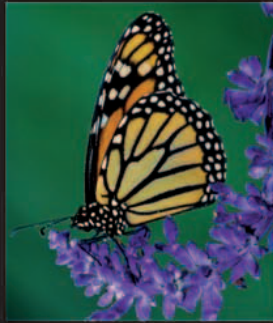


See how large (or small) an animal is compared to an adult human.

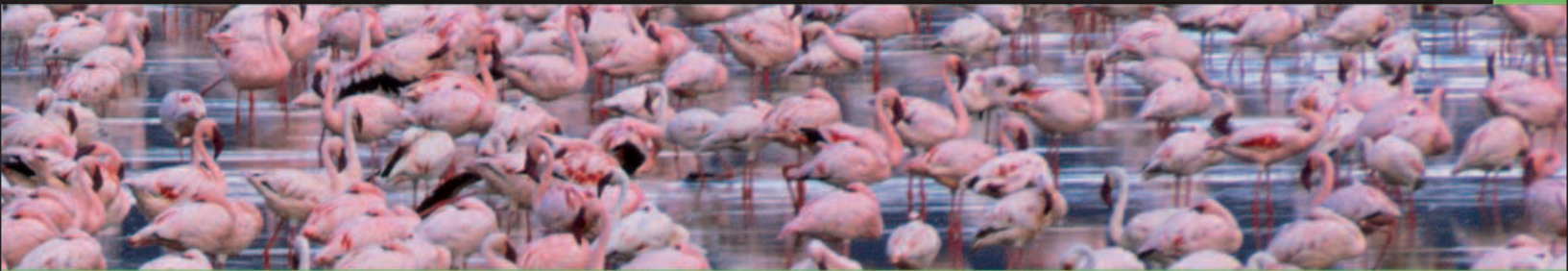
 What features make carnivores such efficient predators?  
*Find out on pages 96–97*

 How many types of feather do birds have?  
*Find out on pages 104–105*






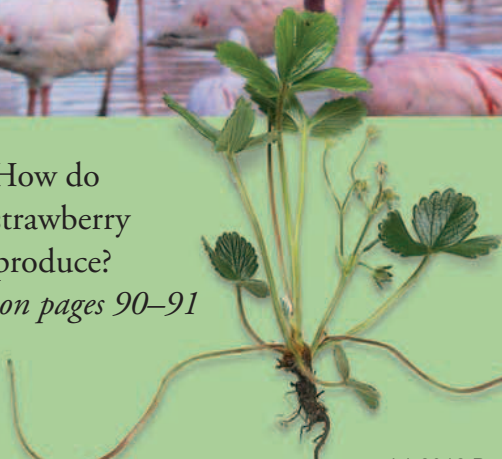
*Definition:* Animals, plants, fungi, protists, and bacteria are the five main groups—or kingdoms—of life on Earth. These life-forms make up the **living world**.




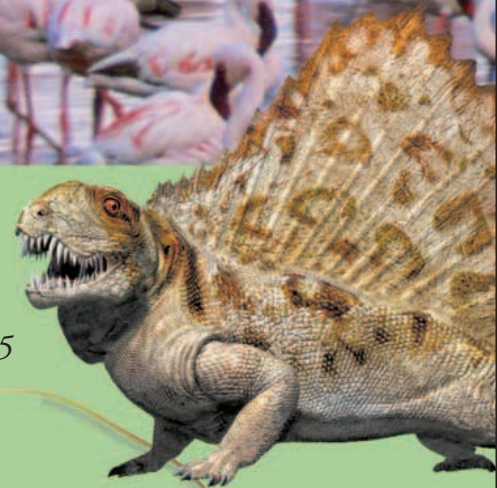
- |   |   |  |  |
|---|---|--|--|
|  Tropical forest and rain forest                       |  Seas and oceans  |  Polar regions and tundra            |  Animal life span in the wild  |
|  Temperate forest, including woodland                 |  Coastal areas, including beaches and cliffs                       |  Mountains, highlands, scree slopes |  Animal not endangered        |
|  Coniferous forest, including woodland                |  Coral reefs and waters immediately around them                    |  Caves                              |  Animal numbers are declining |
|  Grassland habitats: moor, savanna, fields, scrubland |  Rivers, streams, and all flowing water                            |  Urban                              |  Animal endangered            |
|  Desert and semidesert                                |  Wetlands and still water: lakes, ponds, marshes, bogs, and swamps |  Parasite                           |  Animal status unknown        |



 How do strawberry plants reproduce?  
*Find out on pages 90–91*



 When did synapsids roam North America?  
*Find out on pages 124–125*





# Life on Earth

Life on Earth is hugely varied. Sunflowers and sharks look like they have nothing in common, but all living things share certain features: they are made up of cells; they need energy to survive; they have a life cycle; and they can reproduce.

**THE FIVE KINGDOMS**  
Scientists organize all life-forms using a classification system. At the top of the system used in this book are five broad groups, called kingdoms. Every living thing fits into a kingdom based on its cell structure and the way it gets energy. Kingdoms are divided into smaller and smaller groups, based on shared characteristics. The smallest grouping is species.



**Animals** are living things that are made up of many cells (multicelled). They get energy by eating food.



**Plants** are also multicelled. The cell walls are made of cellulose. Plants make their own food through a process called photosynthesis.



**Fungi** are multicelled organisms that do not need sunlight to grow. Many fungi live underground—all that can be seen above ground are the parts that make spores for reproduction, which are called mushrooms.



PHYLUM: **Chordates**—Animals with some form of spine.



CLASS: **Mammals**—These are chordates that nurse their young with milk. Most give birth to live young.



ORDER: **Carnivores**—These mammals have powerful jaws and specialized teeth for killing and eating meat.



FAMILY: **Felids**—These are carnivores that have extending claws. The common name for Felids is "cat."



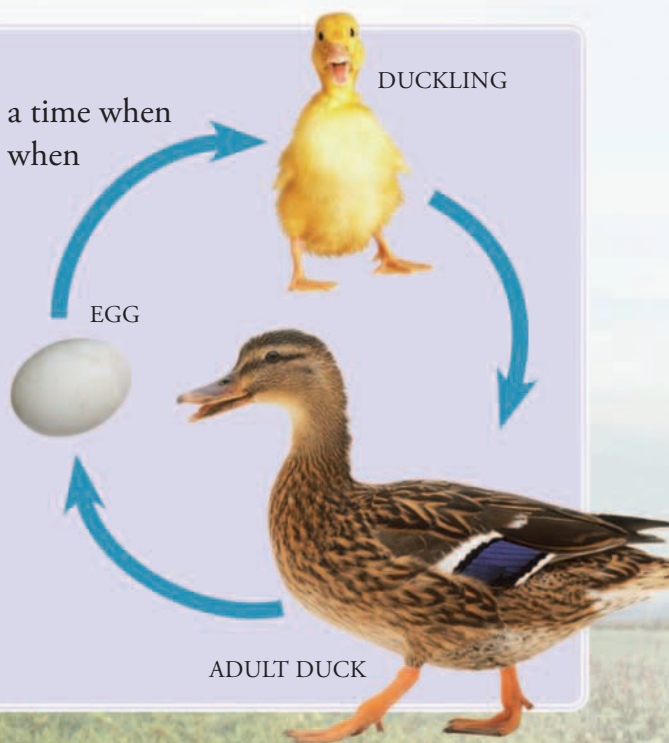
GENUS: **Panthera**—These are large cats that can roar as well as purr.



SPECIES: **Panthera pardus**—This name identifies the roaring cat as a leopard.

## LIFE CYCLE

All living things have a time when they grow and a time when they die. They also reproduce, which ensures the survival of the species. Animals lay eggs or give birth to live young, plants and fungi produce seeds or spores, and bacteria and protists usually divide in two to reproduce.





## FOOD CHAINS

**Desert shrub**  
*Fagonia* sp.

**Gerbil**  
*Meriones* sp.

**Fennec fox**  
*Vulpes zerda*

**Striped hyena**  
*Hyaena hyaena*

▲ **PRODUCERS** such as plants are the first stage in a food chain. Plants need energy from sunlight, nutrients from the soil, and water to grow.

▲ **PRIMARY CONSUMERS**, such as gerbils, are the first animals in a chain. They are herbivores—animals that eat only plants.

▲ **SECONDARY CONSUMERS** are carnivores—animals that eat meat.

▲ **SCAVENGERS AND DECOMPOSERS** Scavengers eat dead animals, helping to break down organic matter. Maggots, fungi, and bacteria are major decomposers.



**Protists** are basic life-forms. Most protists are single-celled and are microscopic, but some group together and are more easily seen, such as algae on a pond.



**Bacteria** are the simplest form of life. They are single-celled organisms that are too small to see without a microscope. Bacteria can live in the air, in water, and even inside bodies.

## FAST FACTS

- The word “organism” refers to any living thing.
- There are different ways of classifying organisms. They change as more information is discovered about species.
- All living things are linked to others. This is how a food chain works: if parts are missing, the chain may collapse. This could lead to species dying out.
- Bacteria can be harmful or helpful: *E. coli* bacteria cause disease, but penicillin can cure some illnesses.
- The organism that makes bread go moldy is a fungus.

## THREATENED SPECIES

**In every kingdom, there are species that are under threat of extinction.**

There are many reasons why a species fails to continue, from habitat loss to disease to poaching (👁️ p. 80–81).

The International Union for the Conservation of Animals (IUCN) has researched more than 1.5 million animal and plant species to create their Red List of Threatened Species. They found that:

- in 2008, nearly 1,000 animals and plants became extinct or extinct in the wild;
- more than 16,000 other species are under threat of extinction.



◀ More than one out of every five mammal species are threatened with extinction, including the Péré David deer.



◀ Nearly 30 percent of amphibians are under threat. Poison dart frogs are being wiped out along with their forest habitat.

## Which species are at risk?



Most of the animals in this chapter appear on the IUCN Red List.



Those with red triangles are at risk of extinction, and may already be extinct in the wild. Yellow triangles show species that are vulnerable—they risk becoming endangered in the near future.



Green triangles mean there is little or no risk of them becoming endangered at present.



▼ Plants are also at risk, with more than 8,000 species under threat, including the lady's slipper orchid.



# Plant life

There are 400,000 identified species of plant in the world. From the tallest redwood tree to the smallest duckweed, and the plainest moss to the most exotic orchid, plants all play a vital role in sustaining life on Earth.

## WHAT IS A PLANT?

A plant is an organism made up of many cells that is able to manufacture its own food. Most plants do this using sunlight, carbon dioxide, and water to make carbohydrates.

The **stem** provides support for the leaves and flower head and carries water, minerals, and food to all parts of the plant.

The main **root**, or taproot, anchors the plant in the ground. Together with the side roots, it absorbs water and minerals from the soil.

The **flower** contains the reproductive parts of flowering plants.

**Leaves** collect sunlight and contain the tiny structures that make food for the plant.

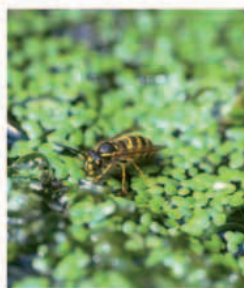
Some plants, such as daisies, have **simple** leaves: a leaf that has just one flat blade.

Other plants have **compound** leaves, made up of smaller leaflets.

## LARGEST AND SMALLEST



■ The world's largest plant is the **giant redwood** tree, at up to 275 ft (84 m) tall with a trunk 36 ft (11 m) in diameter. The largest flower head is that of the titan arum from Sumatra, which grows to about 10 ft (3 m) tall.



■ Some plants are too small to see clearly without a magnifying lens. The tiniest flowering plant is a duckweed known as **watermeal**. A whole plant is about  $\frac{1}{32}$  in (1 mm) long.

## PLANTS ARE ESSENTIAL FOR LIFE...

■ Without plants there would be very little oxygen in the air for us to breathe. Plants help reduce the Greenhouse Effect (👁️ p. 78–79) by using up some of the extra carbon dioxide we produce.



■ Plants and algae form the base of most food chains. Nearly everything we eat comes from plants, or from animals that eat plants. Animals that eat only plants are called herbivores.



■ Plants have many other uses. Without them there would be no lumber for building or burning, and no cotton, coal, paper, or rubber. Many medicines, toiletries, and dyes also come from plants.



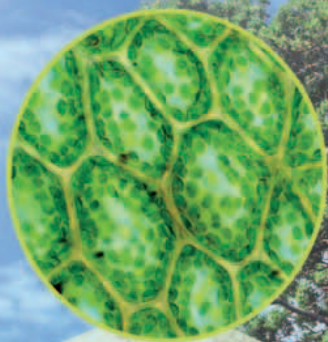


## Photosynthesis

All living things need food for energy but, unlike animals, plants make their own food. The plant's leaves absorb sunlight and a gas called carbon dioxide from the air, while the roots take up water. Inside the leaf, energy from the sunlight is used to turn the carbon dioxide and water into sugary food for the plant. The process is called photosynthesis, which means "making things with light." The plant also creates oxygen as a by-product of photosynthesis, which it releases through its leaves.

*At night the plant takes some of the **oxygen** back in to help it burn its own sugars for energy.*

*The plant's leaves absorb **carbon dioxide** from the air and use it in photosynthesis.*



▲ **INSIDE A LEAF**  
Photosynthesis takes place within tiny structures called chloroplasts, inside leaf cells. Chloroplasts are green because they contain a pigment called chlorophyll.

*Plants need **water** to stay strong and healthy. Water is carried around a tree in minute tubes called xylem.*

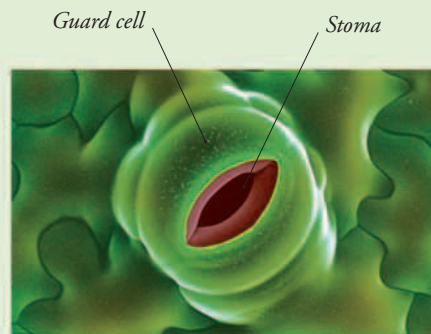
*Tree **roots** can take up as much space underground as branches do above it. They give the tree stability and take up water and minerals.*

WATER



## TAKE A LOOK: TRANSPIRATION

The surface of a leaf is covered in microscopic pores called stomata. When a stoma opens it allows carbon dioxide into the leaf for photosynthesis, and also water vapor to escape in a process called transpiration. The lost moisture is replaced by water drawn up through the roots. Water from the soil contains many of the minerals that the plant needs.



▲ **OPEN STOMA** Each stoma or pore is flanked by a pair of guard cells, which open and close to control the amount of gas and water vapor passing in and out of the leaf.



## Leaf colors

Leaves contain a variety of pigments. In spring and summer the green pigment chlorophyll masks the colors of the others. In winter, lack of sunlight forces deciduous trees to stop photosynthesis. The chlorophyll in their leaves is broken down, allowing other colors—yellow, red, and brown—to show.



# Types of plant

There are two main groups of plant: those that make seeds in order to reproduce, and those that are seedless. Seedless plants reproduce from spores.

## SPORES

Spores are tiny cells that can divide to form a many-celled body. This body contains sex cells that can be fertilized and grow into a new plant.

*Ferns store spores in capsules on the underside of their leaves.*



## SEEDLESS PLANTS



### ■ Mosses

*12,000 species*

Mosses do not have roots. Instead, they take in water through their leaves, which means they can grow without soil. They attach to bare ground, trees, and rock using rootlike hairs called rhizoids.



### ■ Liverworts

*6,000–8,000 species*

Liverworts are the earliest known form of plant life. They are generally small, leafy-looking plants that grow in damp places, and sometimes in water. The umbrella-like structures are reproductive bodies.



### ■ Horsetails

*20–30 species*

We can tell from fossils that today's horsetails look very similar to those living 300 million years ago. Modern horsetails are small plants but the ancient ones grew up to 150 ft (45 m) high and formed great forests.



### ■ Ferns

*Around 12,000 species*

Ferns are typically found in damp, shaded places. They come in a great variety of shapes and sizes, from dainty miniatures to great tree ferns with fronds (leaves) up to 16 ft (5 m) long.

## PLANT EVOLUTION

Seedless plants are the oldest plants on the planet, first appearing about 475 million years ago. Flowering plants are the youngest, a mere 130 million years old.

**!NOW!**

### I'M A SURVIVOR

*Ginkgo biloba* is the sole surviving species of a group of plant that once grew all over the world, but today grows wild only in China. Ginkgo fossils have been found that are 160 million years old—and they show that the plant has not changed in all that time.



## TIMELINE OF PLANT EVOLUTION

475 MILLION YEARS AGO

Liverworts and mosses—the first seedless plants



390–360 MYA

Ferns



360–290 MYA

Conifers—the first seeded plants

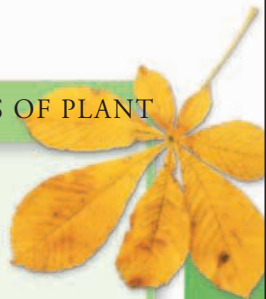


135 MYA

Flowering Plants







## CONIFERS

The group of trees known as conifers produce seeds on cones rather than in flowers. Most conifers are “evergreen” plants, which don’t drop their leaves in the winter. There are 630 species of conifer, including cypresses, firs, pines, larches, and the tallest trees in the world, coastal redwoods. Yew trees are unusual, coneless conifers.



**Cypress** *Cupressus macrocarpa*    **Korean fir** *Abies koreana*    **Norway spruce** *Pinus abies*    **Yew** *Taxus baccata*

## BROADLEAF TREES

Trees that produce their seeds in flowers rather than cones tend to have broad leaves. Most broadleaf trees are “deciduous”—they lose their leaves in winter to save energy.



## FLOWERING PLANTS

Three-quarters of all known plant species are flowering plants, also known as angiosperms. This group includes a huge range of plants, from trees and grasses to garden flowers, and from cacti to carnivorous plants.

### Types of flower

Flowers contain the organs that a plant uses to make seeds and pollen.

▶ **SIMPLE** *Tulips have simple flowers. They are built around a circle, and all the petals look the same.*



▶ **COMPLEX** *Orchid flowers are complex. They have the same parts as simple flowers, but they develop into all kinds of unusual forms to attract the right kind of pollinating insect.*



▶ **COMPOSITE** *Gerberas produce composite flowers. The head is not one flower, but made up of hundreds of little florets.*



▶ **SPIRE** *Gladioli flowers grow in tall spires or inflorescences. The flowers open one at a time, starting from the bottom.*



## TOUGH FLOWERING PLANTS

Some flowering plants have extraordinary abilities to survive in harsh environments.

### ■ No soil

Parasitic plants such as mistletoe can grow without soil, because they tap into a host plant and steal its nutrients instead. Epiphytes such as bromeliads also grow on other plants, usually to help them reach sunlight, but do not damage their hosts.



### ■ Poor soil

Carnivorous plants cannot get all their nutrients from the soil, so they supplement their diet with meat. When a fly lands on a Venus flytrap, the leaves close up and the plant releases juices that help it digest the fly’s body.



### ■ No water

Cacti grow in very dry places. After rain, the cactus absorbs and stores enough water in its thick stem to survive the next dry spell.





# Plant reproduction

Flowering plants and cone-bearing plants (such as conifers) are seed producers. Most flowering plants reproduce through seeds but some have vegetative reproduction, too. In order to produce seeds, a flower must first be pollinated.

## WHAT IS A FLOWER?

Flowers contain a plant's sexual organs. Flowers are often brightly colored or scented to attract pollinators.

*Sepals grow on the outer whorl. In some flowers, they look the same as the petals.*

*The stigma, style, and ovary together are called the **carpel**. They are the female parts of the plant.*

*The stigma receives pollen.*

*The ovary is where seeds are produced.*

*In a simple plant, petals grow in a circle, or whorl.*

*The filaments and anthers together are called **stamens**. They are the male parts of the plant.*

*The **anther** is where pollen is produced.*

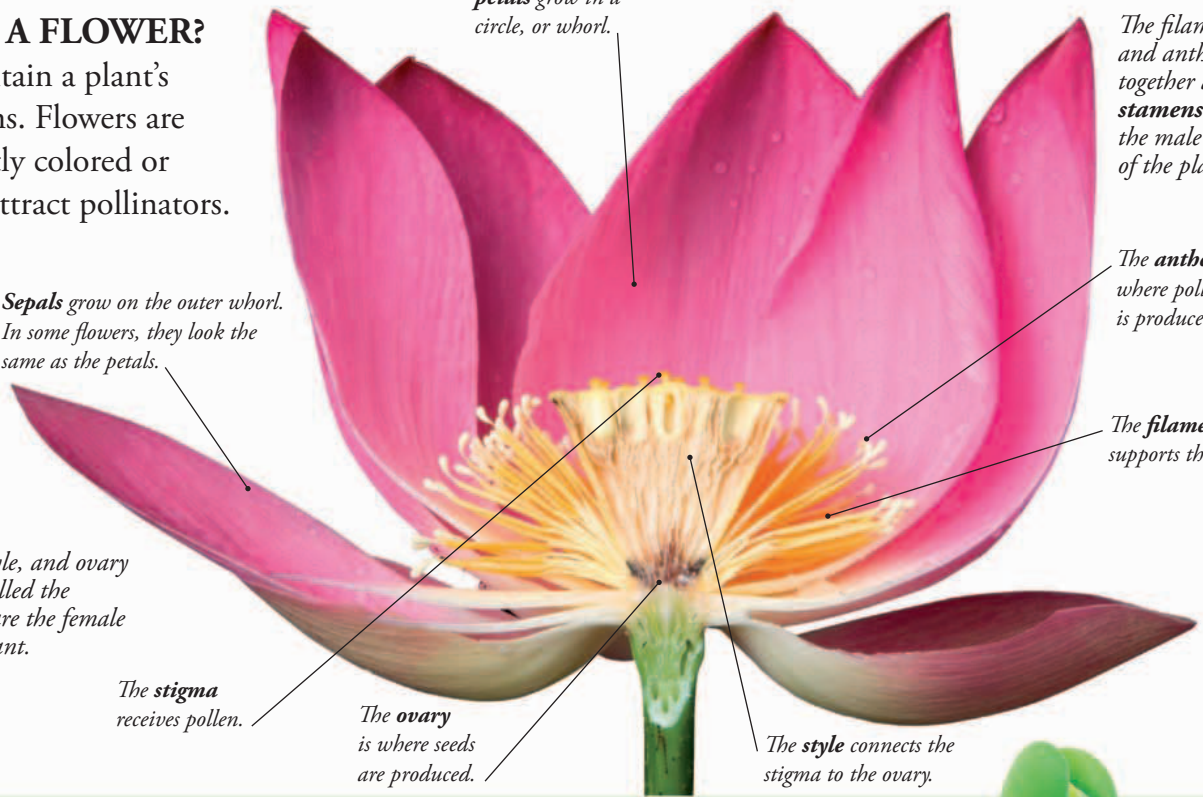
*The **filament** supports the anther.*

*The **style** connects the stigma to the ovary.*



**WOW!**

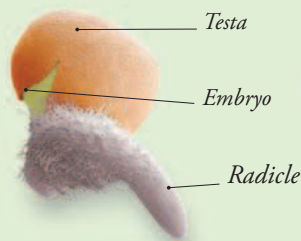
Pollinators such as insects and bats may be attracted to flowers by their scent—but that doesn't mean the flower smells nice to us. Rafflesia flowers fill the air with the smell of rotting meat to attract flies. Yuck!



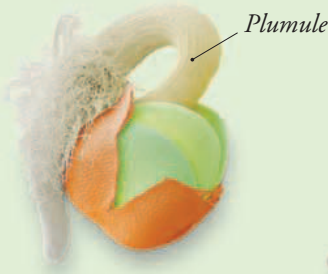
## TAKE A LOOK: GERMINATION

■ Seeds contain everything a plant needs to grow: an embryo and a food supply, which are protected inside a hard coat called a testa.

■ In the right conditions—usually a dark, damp, and warm place, such as in soil—the seed will germinate. First, the seed absorbs water. Then the embryo starts to grow, using its food store. A root appears, followed by a shoot. Seed leaves are attached to this shoot; the first true leaves don't appear until later.



▲ **ROOT** As the embryo starts to grow, the testa splits and the first root, called a radicle, grows downward.



▲ **SHOOT** The first shoot, called the plumule, grows upward. The plumule reaches above ground, and becomes the plant stem.



▲ **SEED LEAF** Some plants have just one seed leaf, but others have two. They contain the remains of the seed's food store.



PLANT REPRODUCTION

■ Flowers attract insects, birds, and mammals, which come to feed on nectar. Bees also collect pollen. Once a plant is fertilized, the flower is no longer needed. The petals die and fall off.



▲ **POLLINATION** *When a bee visits a flower to drink nectar, it picks up pollen from the flower's anthers.*



▲ **FERTILIZATION** *The bee visits a second sunflower and transfers the pollen to the stigmas. This fertilizes the plant.*



▲ **SEEDS** *The pollen grows down the style to the ovary, where it fertilizes an egg cell. A new plant starts to form. This is the seed.*



▲ **DISPERSAL** *In order to grow, seeds need to leave the plant. Birds eat the tasty seeds and pass them through, dispersing them.*

LIVING WORLD

SEED DISPERSAL

■ Many plants produce fruit that encourage animals to eat and disperse their seeds, but not all...



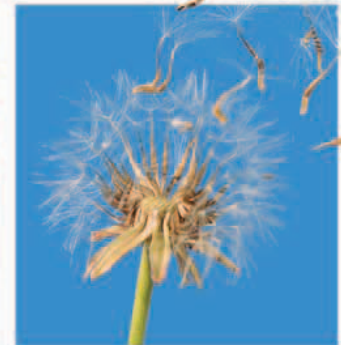
▲ **HITCHING A RIDE** *Burrs become hooked onto animal fur. Their host carries them away, then they fall off to the ground.*



▲ **FORCE** *When the seeds are ready, Himalayan balsam flowers burst open. The force sends the seeds flying out.*



▲ **WATER** *Coconut palms use the sea to disperse their seeds. Coconuts have been known to drift for huge distances.*



▲ **WIND** *Dandelion seeds are light and fluffy. Like tiny parachutes, they catch the wind to disperse far and wide.*

VEGETATIVE REPRODUCTION

■ Some flowering plants don't only reproduce through seeds. Instead, they form plantlets that are genetically identical to the parent plant.



▲ **STOLONS** *Strawberries have stolons—stems that grow along the ground. New plants grow from leaf nodes along the stolon.*



▲ **TUBERS** *such as Jerusalem artichokes store food for the parent plant, but they can also sprout and grow into new plants.*



▲ **RHIZOMES** *Iris spread through underground stems called rhizomes. The rhizome divides and forms new plants.*



▲ **BULB** *Onions and tulips grow from bulbs, which are buds that are surrounded by very swollen leaves.*

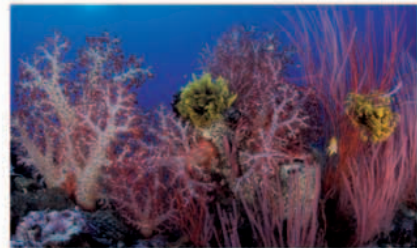


# Animal life

There are more than 1.2 million identified species of animal, making this the largest kingdom of living things.

## WHO'S WHO?

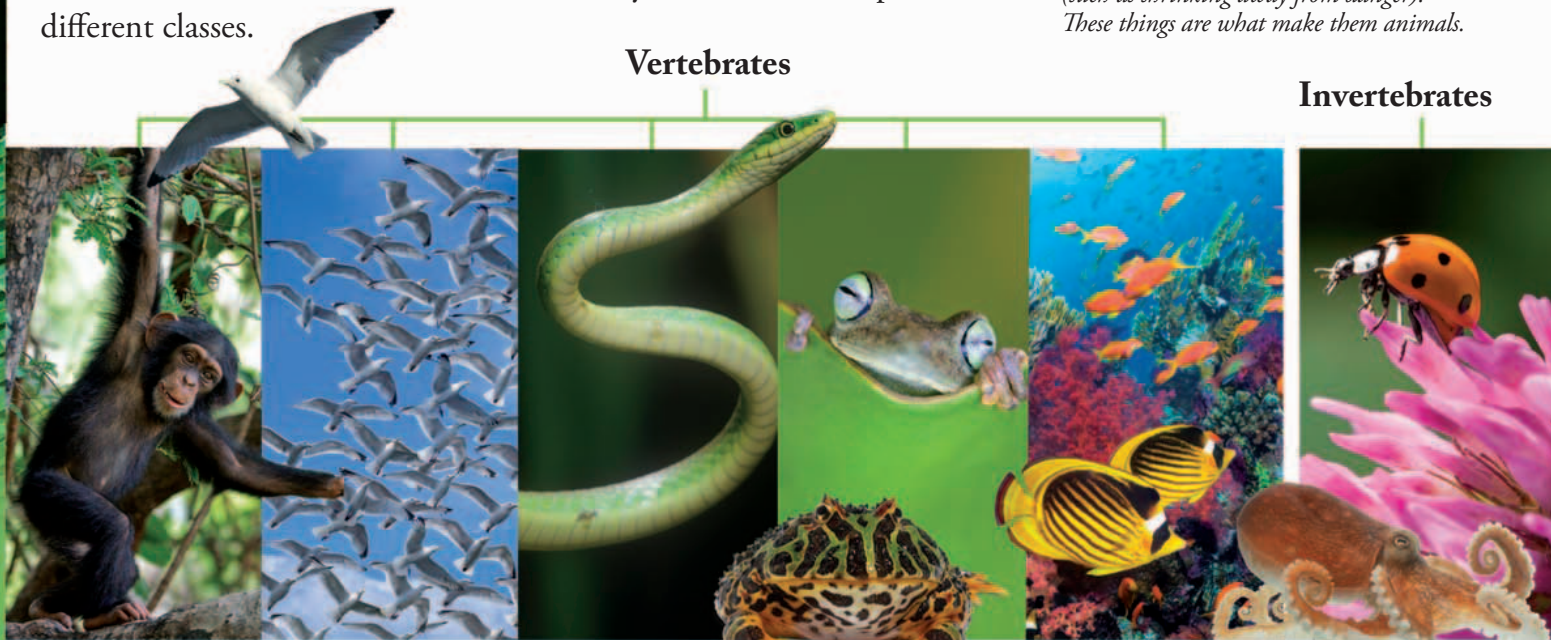
Most animals are invertebrates: they have no backbone. Animals with backbones are known as vertebrates, and they can be divided up into different classes.



▲ **THOSE ARE ANIMALS?**  
*It's usually easy to tell an animal from a plant—animals are the ones that move around. But this isn't always the case. Corals look like plants and have limited movement. However, they take in food to get energy and they have nerves that control their reactions (such as shrinking away from danger). These things are what make them animals.*

### Vertebrates

### Invertebrates



▲ **MAMMALS**  
*There are more than 5,000 species of mammal. What makes this class unique is that the young feed on milk from their mothers. Mammals are warm-blooded, most have a hairy body, and most give birth to live young.*

▲ **BIRDS** *There are about 9,500 species of bird. They are warm-blooded, have wings and a bill, and a body covered in feathers. All birds lay eggs and most can fly.*

▲ **REPTILES**  
*The 8,000 species of reptile are recognized by their scaly skin. They are cold-blooded and lay eggs to reproduce.*

▲ **AMPHIBIANS**  
*Most of the 6,000 species of amphibian live part of their lives in water and part on land. They are cold-blooded.*

▲ **FISH** *This is an informal group of three different classes, which together have 29,000 species. All fish are cold-blooded and live in water.*

▲ **INVERTEBRATES**  
*An informal grouping of about 29 major groups (phyla), the invertebrates include all those animals that do not have a backbone. Worms, insects, shrimps, jellyfish, and octopuses are all invertebrates.*

Leopard tortoise



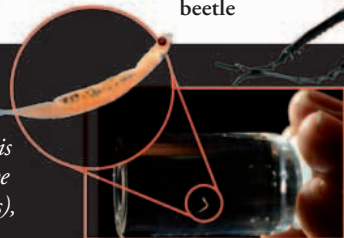
Rhinoceros beetle



## RECORD BREAKERS



**BIGGEST, HEAVIEST, LOUDEST**  
*At up to 100 ft (30 m) long, the blue whale is easily the biggest animal on Earth. It's also the heaviest, weighing 135 tons (120 metric tons), and the loudest. At 188 decibels, its calls are louder than a jet engine. A blue whale's heart is the size of a small car and its largest blood vessel is wide enough for a small person to crawl inside. Blue whales are threatened with extinction due to overhunting in the past.*



▲ **SMALLEST VERTEBRATE**  
*Australia's infantfish is less than 1/2 in (1 cm) long.*

▲ **STRONGEST**  
*The rhinoceros beetle can lift 850 times its own weight. If the beetle weighed as much as a human it could lift at least two fully loaded double-decker buses.*



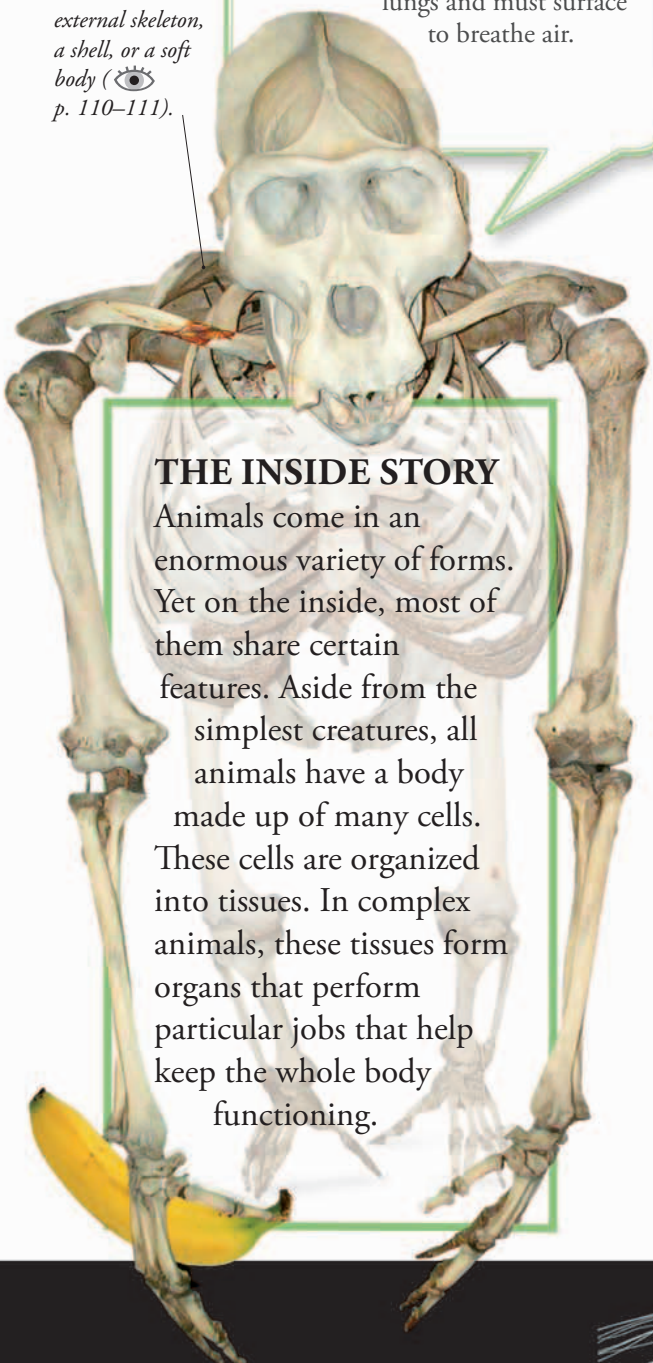
The bodies of vertebrates, such as apes, are supported by an internal skeleton made of bone or cartilage. Invertebrates may have a hard external skeleton, a shell, or a soft body (👁️ p. 110–111).

TELL ME MORE...

Animals need oxygen to survive. Many species that live on land have lungs to breathe air; those that live underwater, such as fish, have gills to filter oxygen from the water. Aquatic birds and mammals have lungs and must surface to breathe air.

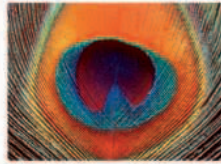
THE INSIDE STORY

Animals come in an enormous variety of forms. Yet on the inside, most of them share certain features. Aside from the simplest creatures, all animals have a body made up of many cells. These cells are organized into tissues. In complex animals, these tissues form organs that perform particular jobs that help keep the whole body functioning.



ON THE OUTSIDE

Animals have different body coverings that protect them from heat and cold, from waterlogging or drying out, and from all kinds of attack. Birds are the only animals to have feathers; reptiles and most fish have scales; and mammals are the only animals to have hair on their bodies.



Bright colors and patterns can be used to attract mates...



... as a warning that the animal is foul-tasting or poisonous...



... or as camouflage so the animal blends in with its surroundings.



▲ SOCIAL Elephants live in large herds

▶ SOLITARY Pandas live alone



Solitary or social?

Some animals are solitary: they hunt, eat, sleep, and live alone and only seek out other members of their species to mate and produce offspring. Other animals live in pairs or groups, which increases their chances of survival. Members of a group may work together to find food, defend a territory, rear young, or keep watch for predators.

Body heat

Mammals and birds are warm-blooded, or endothermic—they generate their own body heat using energy from food and can control their body temperature. Most other animals are ectothermic, which means they cannot control their temperature naturally. When they want to warm up they sunbathe, and if they are too hot they seek shade to cool down.

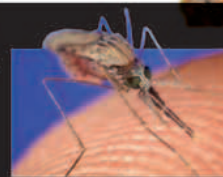
Ectothermic animals such as lizards can be seen basking in the morning sunlight in order to warm their bodies.



◀ FASTEST The peregrine falcon can swoop at a breathtaking 220 mph (360 km/h) in unpowered flight. The fastest creature on land is the cheetah, and in water is the sailfish. Both can reach 70 mph (110 km/h).



▲ MOST DEADLY A single sea wasp jellyfish has enough venom to kill 60 men. The venom of cone snails and some fish is even more toxic.



▲ BIGGEST KILLER Female Anopheles mosquitoes kill more than a million people each year by infecting them with malaria.



▲ LONGEST LIFESPAN A Madagascan radiated tortoise like this one is known to have lived at least 188 years. Bowhead whales may survive even longer, maybe as long as 250 years.



# Mammals

Mammals are vertebrates that feed their young on milk produced by the mother. The milk is made in her mammary glands, which is why the group is called “mammals.” Most mammals give birth to live young.

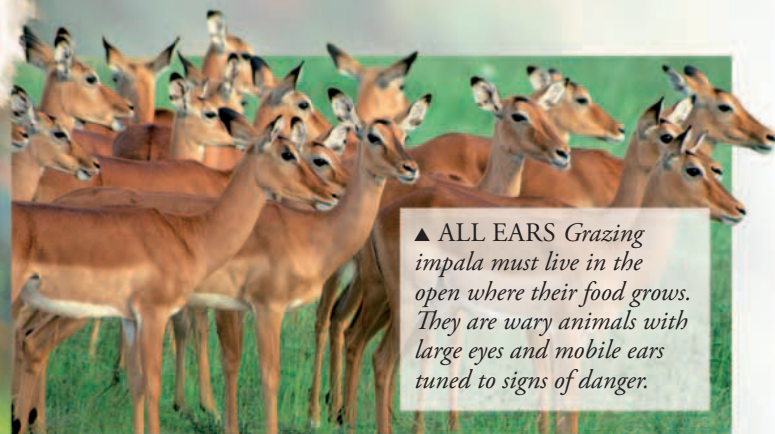
## WHAT IS A MAMMAL?

All mammals have a lower jaw made up of just one bone. This is how scientists identify mammal fossils, long after mammary glands and hair have disappeared.



HYENA SKULL

Mandible, or jawbone



▲ ALL EARS *Grazing impala must live in the open where their food grows. They are wary animals with large eyes and mobile ears tuned to signs of danger.*

## HAIR

Mammals are the only animals to have hair. Hair is made from keratin, the same material found in fingernails, fish scales, and bird feathers. A dense coat of hair is called fur; its main purpose is to keep the animal warm. Hair also appears in other forms, such as protective spines (as in hedgehogs and echidnas) and the sensitive facial whiskers of other mammals.

**Short-beaked echidna**  
*Tachyglossus aculeatus*



## Browsers and grazers

Nearly all hoofed mammals are herbivores—they eat only plants. Some are browsers, which means they nibble leaves and shoots from trees and shrubs; others are grazers that eat mainly grass. Plant matter, especially grass, is hard to digest, so many of these animals ruminate, or chew the cud. After swallowing a meal, they lie down to rest while bacteria in their stomachs weaken the tough plant cell walls. Then the animal regurgitates its food (now called cud) and chews it again to help release nutrients.





## ORDER, ORDER!

There are more than 5,000 species of mammal, arranged into 28 orders. The members of an order tend to be descended from a shared ancestor and are united by similar anatomy or lifestyle. For example, camels, deer, hippopotamuses, giraffes, cattle, whales, and dolphins are all families within the order Cetartiodactyla.

### BATS

Bats are the only mammals that can truly fly (not just glide). All bats have wings, which are, in fact, delicate webbed hands. Hearing is very important to bats: they can find prey and avoid obstacles in total darkness by listening to the way their calls echo off nearby objects.



### POUCHED MAMMALS

There are more than 330 species of pouched mammal in seven orders, including kangaroos, opossums, and the koala. Commonly called marsupials, these mammals give birth to very tiny young. The newborns crawl inside their mother's pouch, where they feed on milk and continue to grow.



► **SAFE INSIDE**  
*A joey in its mother's pouch.*



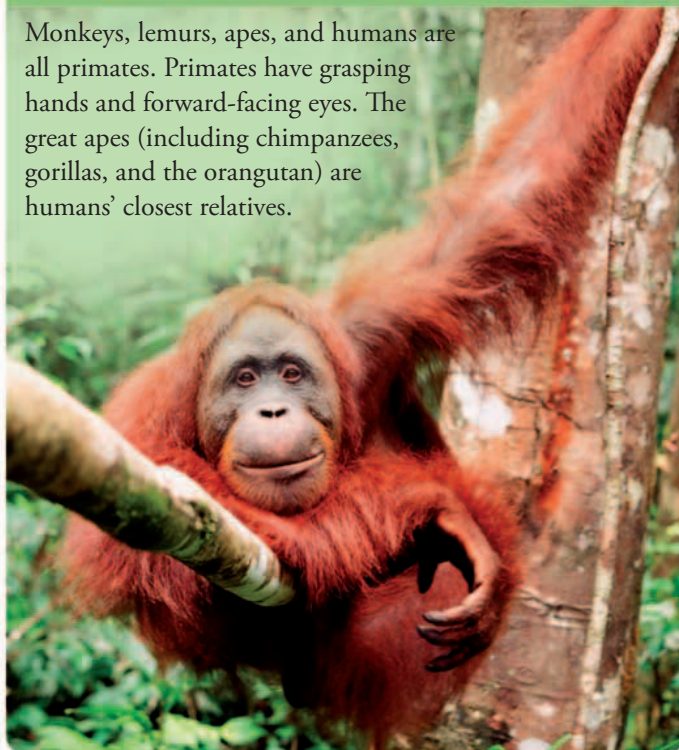
### MONOTREMES

There are five species of mammal that don't give birth to live young, but instead lay eggs. They are called monotremes and include the duck-billed platypus. Once hatched, young monotremes feed on their mother's milk, just like other mammals.



### PRIMATES

Monkeys, lemurs, apes, and humans are all primates. Primates have grasping hands and forward-facing eyes. The great apes (including chimpanzees, gorillas, and the orangutan) are humans' closest relatives.



### CARNIVORES

◀ **LESSON TIME**  
*Polar-bear cubs learn to hunt by watching their mother.*

There are 12 families of meat-eating mammals grouped into one order called carnivores. They have bodies that are adapted to hunting and eating flesh.



**Leopard**  
*Panthera pardalis*









# Mammal record breakers

Mammals come in a staggering variety of forms and have mastered almost every habitat on Earth. They walk, run, swim, burrow, and fly, and one species, our own, has even been to the Moon.

**Human beings**   **66**

Humans (species *Homo sapiens*) are mammals from the great ape family. We can live to around 125 years, but the worldwide average is 66 years. We inhabit every continent except Antarctica, making us the most **widespread** mammals.




   **Hog-nosed bat**  
*Craseonycteris thonglongyai*  
■ **Length** 1¼ in (30 mm)

The world's **smallest mammal** is also known as the bumblebee bat. It weighs about half as much as a cube of sugar.



     **65**  
**African savanna elephant**  
*Loxodonta africana*  
■ **Weight** 6½ tons (6 metric tons)

The **biggest mammal on land** reaches full size at about 20 years of age, but its tusks keep on growing.



**30**   **Giraffe**   
*Giraffa* sp.  
■ **Height** 17½ ft (5.3 m)  
The **tallest** mammal's long legs and neck allow it to reach leaves on high branches.



   **50**  
**Mountain gorilla**  
*Gorilla beringei*  
■ **Weight** 440 lb (200 kg)

Compared to the size of its body, a male gorilla has the **longest arms** of any mammal.

  **90**  
**Blue whale**  
*Balaenoptera musculus*  
■ **Length** 100 ft (30 m)



With a body that is 50 percent fat after feeding on its mother's fatty milk, a ringed seal pup is the **fattest** wild mammal.

  **43**  
**Ringed seal**  
*Phoca hispida*  
■ **Length** 4¼ ft (1.3 m)





**Sea otter**  
*Enhydra lutris*  
■ **Length** 4¼ ft (1.3 m)



With 800,000 hairs per square inch (125,000 hairs per cm<sup>2</sup>), sea otter fur is waterproof, warm, and the **densest fur** of any mammal.



**Striped skunk**  
*Mephitis mephitis*  
■ **Length** 2¼ ft (68 cm)



The stinking spray from a skunk is used as a defense against predators—and makes it the **smelliest** mammal.



**Three-toed sloth**  
*Bradypus variegatus*  
■ **Length** 2 ft (60 cm)

Sloths are the **slowest** mammals, averaging 0.1 mph (0.16 km/h) when moving among trees. They often remain motionless for hours.



**Cheetah**  
*Acinonyx jubatus*  
■ **Length** 4½ ft (1.35 m)



Over short distances, a cheetah can sprint at up to 60 mph (95 km/h) in pursuit of prey, making it the **fastest** mammal.



Camels are the **biggest drinkers**. Bactrians can drink 120 pints (57 liters) in one session.



**Bactrian camel**  
*Camelus bactrianus*  
■ **Height** 7½ ft (2.3 m)



The blue whale is the **largest living animal** on Earth. Its voice carries up to 500 miles (800 km) through the ocean.

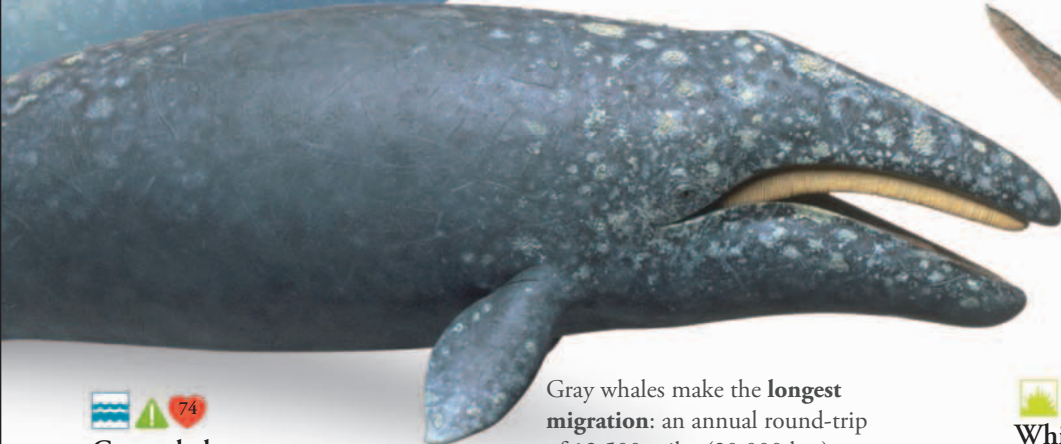


**Scimitar-horned oryx**  
*Oryx dammah*  
■ **Length** 5½ ft (1.7 m)

These antelope have been hunted to extinction in the wild, making them among the **rarest** mammals.



**Gray whale**  
*Eschrichtius robustus*  
■ **Length** Up to 50 ft (15 m)



Gray whales make the **longest migration**: an annual round-trip of 12,500 miles (20,000 km) from the Arctic to breeding grounds off Mexico.



**White rhinoceros**  
*Ceratotherium simum*  
■ **Length** 14 ft (4 m)



Rhinos have the **thickest skin**, which acts as armor. In vulnerable places like the shoulders it can be almost 2 in (5 cm) thick.



# Killer carnivores

Many animals are described as carnivorous: it means that they eat meat. But there is also an order of mammals called carnivores, which have unique features such as sharp cheek teeth. Many can kill prey bigger than themselves.

## BUILT TO HUNT

A typical carnivore has a body that is adapted to hunting. It has good eyesight, hearing, and sense of smell to locate prey, and can run fast or for long distances to give chase. Cats have sharp claws to grab prey and bring it down, while powerful jaws and teeth bite to kill.

## ON THE MENU

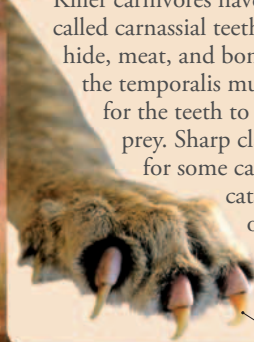
- **Carnivores** Different carnivore species eat different prey. Lions hunt in prides to kill large animals such as wildebeest; otters hunt alone, feeding on fish and shellfish.
- **Herbivorous carnivores** Pandas are largely herbivorous—they rarely eat meat at all, but fill up on plants. They have flat cheek teeth for chewing bamboo, rather than sharp teeth for tearing meat.
- **Omnivorous carnivores** Many carnivores, including foxes and skunks, are omnivorous—they eat all kinds of food, from plants to birds' eggs to frogs... In fact, almost anything they can find.



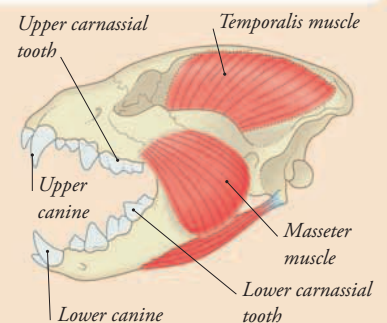
**Scavengers** Not all carnivores are predators. Hyenas are very good at hunting, but they will also scavenge—eat an animal that is already dead, killed by others or by natural causes.

## TAKE A LOOK: JAWS AND CLAWS

Killer carnivores have four sharp cheek teeth, called carnassial teeth, which can cut through hide, meat, and bone. A huge muscle called the temporalis muscle gives enough power for the teeth to break bones or suffocate prey. Sharp claws are equally important for some carnivores. Lions and other cats use their claws to hold onto prey, in defense, for climbing, and for grip when running.



Lion's sharp claws



HYENA SKULL



## Snow leopard

*Panthera uncia*



- **Length** 3¼–4¼ ft (1–1.3 m)
- **Weight** 55–165 lb (25–75 kg)
- **Location** Central, southern, and eastern Asia

The endangered snow leopard has a thick tail that's around the same length as its body. This gives the cat balance when climbing mountain slopes and hunting for prey, such as wild sheep.



## Red panda

*Ailurus fulgens*



- **Length** 20–25 in (50–64 cm)
- **Weight** 6½–13 lb (3–6 kg)
- **Location** Southern and south eastern Asia

Red pandas are not pandas, nor any other type of bear. They are more closely related to raccoons. However, like giant pandas, they mostly eat bamboo. Red pandas are rare and solitary (they live alone). They are known for being shy, and spend most of the time hidden up in trees, where they find food, hide from predators, and even sunbathe in the winter. It can get very cold in the pandas' natural habitat—temperate mountain forests.



## Least weasel

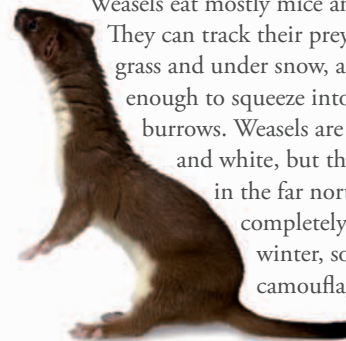
*Mustela nivalis*



- **Length** 9½ in (24 cm)
- **Weight** 9 oz (250 g)
- **Location** North America, Europe, and northern, central, and eastern Asia

Weasels eat mostly mice and voles.

They can track their prey through thick grass and under snow, and are small enough to squeeze into mouse burrows. Weasels are usually brown and white, but those that live in the far north turn completely white in the winter, so they are camouflaged in snow.



## Lion

*Panthera leo*



- **Length** 5½–8¼ ft (1.7–2.5 m)
- **Weight** 330–550 lb (150–250 kg)
- **Location** Sub-Saharan Africa and South Asia

Lions are the only big cats to live in groups, called prides. There may be up to 10 lionesses and their cubs in a pride, with two or three male lions. Lionesses often work together to hunt and kill prey for the pride.



## Eurasian badger

*Meles meles*



- **Length** 35 in (90 cm)
- **Weight** 75 lb (34 kg)
- **Location** Europe and eastern Asia

Badgers live in groups in setts—underground dens and tunnels they dig out with their strong claws. Badgers are nocturnal (active at night), but have poor eyesight, so hunt mainly by smell. Their main diet is earthworms.



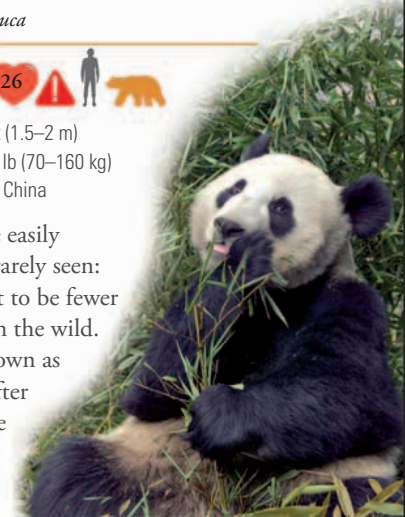
## Giant panda

*Ailuropoda melanoleuca*



- **Length** 5¼–6¾ ft (1.5–2 m)
- **Weight** 155–350 lb (70–160 kg)
- **Location** Central China

Giant pandas are easily recognized, but rarely seen: there are thought to be fewer than 1,600 left in the wild. They are also known as bamboo bears, after their main source of food.



## Gray wolf

*Canis lupus*



- **Length** 4¼–6½ ft (150–200 cm)
- **Weight** 44–130 lb (20–60 kg)
- **Location** North America, eastern Europe, and Asia

All domestic dogs have evolved from the gray wolf, the largest member of the dog family. Gray wolves hunt in packs to kill large animals. Each pack has a territory where it lives and hunts, and wolves will howl to stop other packs from straying into their patch.



## Tiger

*Panthera tigris*



- **Length** 9¼ ft (2.8 m)
- **Weight** 575 lb (260 kg)
- **Location** Southern and eastern Asia

Tigers ambush their prey, which includes deer and cattle. They silently prowl in tall grasses, camouflaged by their stripes. With a sudden pounce, the tiger leaps onto its prey, bringing it down and killing it by breaking its neck or biting its throat, suffocating it.



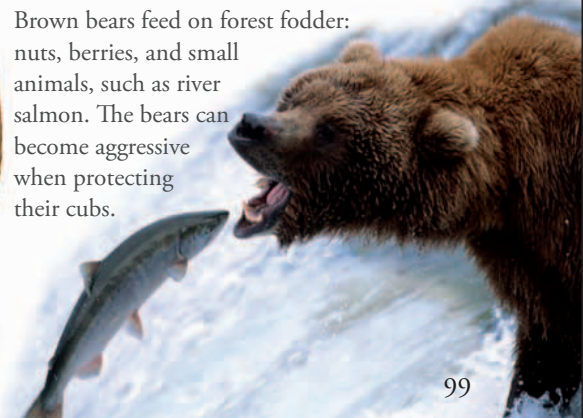
## Brown bear

*Ursus arctos*



- **Height** 10 ft (3 m)
- **Weight** 1,700 lb (780 kg)
- **Location** Northern North America, northern and eastern Europe, and northern Asia

Brown bears feed on forest fodder: nuts, berries, and small animals, such as river salmon. The bears can become aggressive when protecting their cubs.



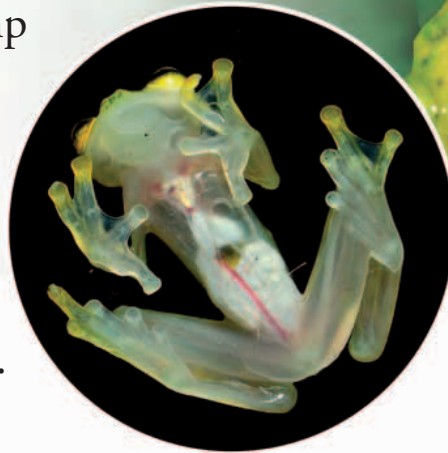


# Amphibians

Most amphibians begin life in water breathing with gills and then venture onto land as adults, where they breathe using lungs and through their skin. They live in damp places, and most return to the water to breed. There are three groups of amphibian: frogs and toads, newts and salamanders, and caecilians.



▲ **GLASS FROG**—Frogs have delicate skin. A glass frog's skin lacks strong pigment and is almost transparent.



## Gills, lungs, and skin

Some salamanders spend their whole lives in water and may keep their tadpole gills even as adults (although they do have lungs as well). Others live entirely on land, where some manage without lungs. They absorb oxygen directly into their bloodstream through their thin skin. Keeping the skin moist helps the oxygen pass through.

## FAST FACTS

- There are around 6,000 amphibian species.
- Amphibians are cold-blooded, and have no hair or scales.
- Most adult amphibians are carnivorous, eating insects, worms, and even birds and snakes. Tadpoles start life as vegetarians.
- All amphibians lay eggs. Some lay just one or two eggs at a time, but others can lay up to 50,000.

## FROM EGG TO ADULT

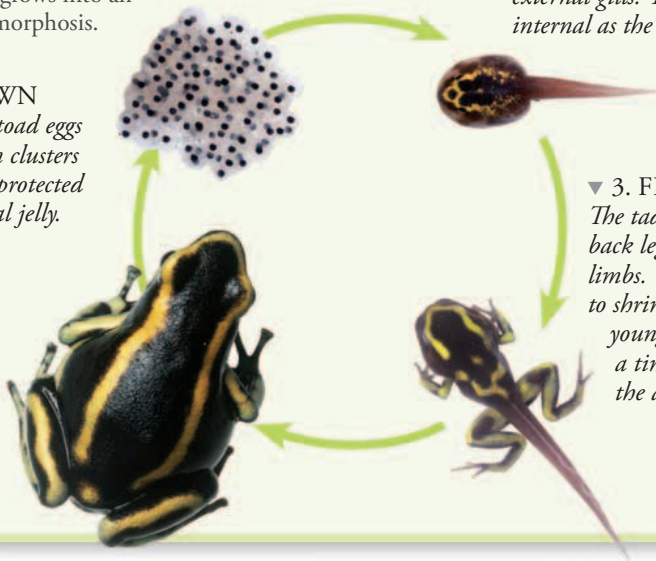
Young amphibians such as this frog hatch as larvae (tadpoles) that look nothing like their parents. The series of changes that take place as a larva grows into an adult is called metamorphosis.

- ▶ **1. SPAWN**  
Frog and toad eggs are laid in clusters or strings protected by a special jelly.

- ▼ **2. TADPOLE** This young tadpole has yet to develop external gills. The gills become internal as the limbs develop.

- ▼ **3. FROGLET**  
The tadpole first grows back legs, then front limbs. The tail begins to shrink until the youngster resembles a tiny version of the adult.

- ▶ **4. FROG**  
The adult lives mostly on land but is also happy in water. It breathes using lungs and through its skin.



Bright colors warn predators



▲ **POISON!** Amphibians have glands in their skin that ooze toxins. The foul taste deters potential predators and may kill them. Some tree frog toxins are used to make deadly poison-tipped darts.



## Golden poison dart frog

*Phylllobates terribilis*



- **Length** 1¼–1¾ in (3–4.5 cm)
- **Weight** ⅛–¼ oz (3–5 g)
- **Location** Colombia, South America

This frog's striking colors carry a serious warning. The toxin that secretes from glands in its skin is the most deadly poison produced by any vertebrate animal, and predators will avoid contact with the frog at all costs. There are three varieties of poison dart frog—gold (like this one), green, and orange.



## European common frog

*Rana temporaria*



- **Length** 2¼–3½ in (6–9 cm)
- **Weight** 1–1¼ oz (25–35 g)
- **Location** Europe

A familiar animal in Europe, the common frog lives and breeds in pools and damp places. In climates with harsh winters it may hibernate for several months in a moist burrow or in mud at the bottom of a pool. Prey, including slugs, worms, and insects, are whipped into the frog's large mouth with its sticky tongue.



## Tiger salamander

*Ambystoma tigrinum*



- **Length** 6–12 in (15–30 cm)
- **Weight** 4–6 oz (100–150 g)
- **Location** Most of North America

Like most amphibians, this large salamander begins life in water. Most metamorphose into land-dwelling adults but some manage to mature and breed without ever leaving the water. On land, tiger salamanders live in grasslands or woodland edges, where they hunt insects, worms, and even mice and frogs.



LIVING WORLD

## Oriental fire-bellied frog

*Bombina orientalis*



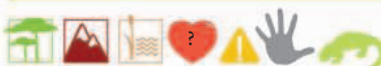
- **Length** 1¾–3¼ in (4–8 cm)
- **Weight** ¾–1 oz (20–30 g)
- **Location** China, Russia, and Korea

The magnificent colors of the fire-bellied frog earn the species its name and warn predators about the poison glands in its skin. The frogs live in humid forests and spend most of their time wallowing in shallow water. Their vision is limited to detecting movement, so potential prey that does not move may be lucky and get away.



## Emperor newt

*Tylotriton shanjing*



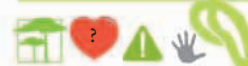
- **Length** 20 in (17 cm)
- **Weight** Exact weight unknown
- **Location** Yunnan Province, China

This handsome newt is at risk in its native China, where it is collected for food, the pet trade, and for use in traditional medicine. Adults live on land most of the year, but return to the shallow pool where they were born to find a mate and lay eggs, which are deposited carefully on water weeds. The name “*shanjing*” means mountain spirit in Mandarin.



## Caecilian

*Gymnopsis multiplicata*



- **Length** 20 in (50 cm)
- **Weight** Exact weight unknown
- **Location** Tropical forests

This strange legless and eyeless creature belongs to the smallest group of amphibians, the caecilians. They spend their lives burrowing through the warm, damp leaf litter or soil of tropical forests. Earthworms happen to be the caecilian's favorite prey, which they hunt by smell, using short tentacles to pick up the earthworm's faint chemical signals. Rather than spawning eggs, this species gives birth to live young that look like miniature adults.



### TAKE A LOOK: FROG FEET

Amphibians usually live in damp, humid, or sheltered places, which helps them keep their skin moist. Their ability to swim, walk, hop, climb, and even glide means they are able to live a wide variety of lifestyles. The frogs shown here have feet adapted to very different habitats.



▲ **STICKY FEET** *Tree frogs have sticky toe pads to provide extra grip.*



▲ **DIRTY FEET** *Burrowing frogs have strong feet for loosening and shoveling soil.*



▲ **WEBBED FEET** *Common frogs have webbed, flipperlike hind feet to help them swim.*



# Reptiles

Reptiles are cold-blooded vertebrates that have tough skin covered in scales. The scales are made of keratin—the same material as mammal hair and bird feathers. There are nearly 8,000 species of reptile, grouped in four orders. The biggest order is snakes and lizards.



**Panther chameleon**  
*Furcifer pardalis*

## FEARSOME FANGS

Some snakes have venom glands just behind their fangs. Venom is used to kill prey, and sometimes in defense. Baring fangs is a warning to attackers to back off.



**Western diamondback rattlesnake** *Crotalus atrox*



**TAKE A PICTURE**

A dione ratsnake (*Elaphe dione*) begins "sloughing" its skin. Snakes shed their skin up to eight times a year.



**Emerald tree boa (juvenile)**  
*Corallus caninus*

## BENDING BACKBONE

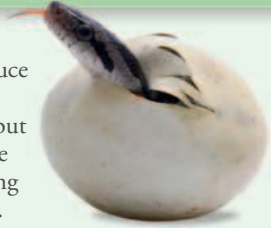
A snake's backbone is incredibly flexible. Tree boas coil around branches to rest and to spot prey. Desert vipers squeeze under rocks for shade. Sidewinding snakes zip across the ground in S-shaped waves.



**Thorny devil**  
*Moloch horridus*

## REPTILE EGGS

Although some snakes and lizards give birth to live young, most reptiles reproduce by laying eggs. Some look like birds' eggs—they have hard, rounded shells—but most eggs have softer, leathery shells. The hatchlings break through their shells using a sharp "egg tooth," which then falls out.



◀ **SNAKE** Young snakes coil up tightly inside a shell. Some can be up to seven times longer than their egg.



▲ **LIZARD** Leopard geckos lay a clutch of two long, sticky eggs in their underground burrows.



◀ **TORTOISE** Large tortoises and turtles, such as leopard tortoises, lay almost perfectly round eggs.

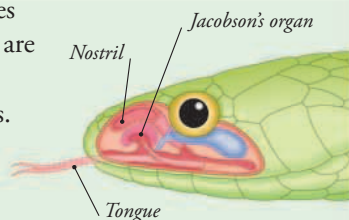
## TAKING A STAND

A reptile's legs stick out at right angles to its body (unlike mammals' and birds', which do not). This gives them a very sturdy frame for walking on uneven land.



## SNAKES

Despite having no limbs, snakes are incredible predators. There are around 2,900 species of snake, and 300 of these are venomous. Other snakes are constrictors: they coil around their prey and squeeze until it suffocates.



### ▲ JACOBSON'S ORGAN

*A snake often hunts by smell and by tasting the air—picking up scents with its tongue. It uses its Jacobson's organ to analyze the scent for signs of prey.*

◀ **DEADLY GRIP** *A rock python kills a gazelle.*

## LIZARDS

There are 4,500 species of lizard, from the enormous komodo dragon to the tiny pygmy chameleon. Most of them have long tails. Some lizards, mostly skinks, have an interesting defense technique: if a predator catches their tail, it can break off so the lizard can run free. Eventually the tail will grow back.



### ◀ SMALLEST & LARGEST ▶

*At up to 10 ft (3 m) long, the komodo dragon is 60 times the length of the 2 in (5 cm) pygmy chameleon.*

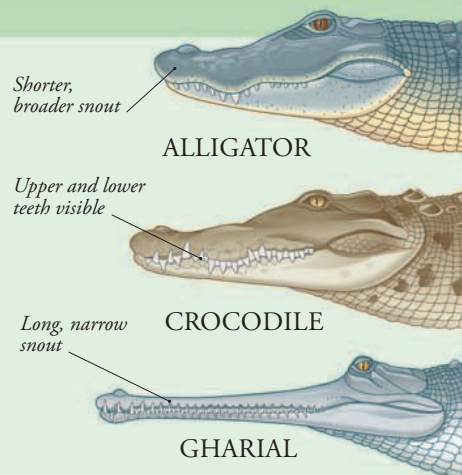


## CROCODILES AND ALLIGATORS

There are 23 species of crocodilian, which have flat, wide bodies, powerful tails, and menacing jaws. They have eyes on the tops of their heads and nostrils on the tops of their noses so they can see and breathe while lying submerged in water, which is where they wait to ambush prey. Fish, and mammals that come down to a lake or river to drink, are the main targets: caught in the crocodile's immense jaws, mammals are dragged into the water and drowned. The crocodile can safely open its mouth under water: it has a flap of skin that it closes across the back of its throat.



▲ **CAUGHT** *Crocodiles that live in the Grumeti River, Africa, take advantage of the wildebeest migration that crosses the river.*



Shorter, broader snout

ALLIGATOR

Upper and lower teeth visible

CROCODILE

Long, narrow snout

GHARIAL

▲ **SNOUTS** *Alligators have shorter, wider snouts than crocodiles; gharial snouts are the narrowest. Only the alligator's top teeth can be seen when its mouth is shut.*

## TORTOISES AND TURTLES

The 255 species of tortoise, turtle, and terrapin are easily recognized by their hard shells. They move slowly, and so most are herbivorous (eat plants), since they are too slow to catch prey. Turtles are more likely to be carnivorous (eat meat): they lie in wait for fish to swim past, then snap their jaws around the prey.



▲ **LAND AND SEA** *Tortoises live on land, but turtles are water-based.*

◀ **LONG NECK** *The common snake-necked turtle uses its long neck to lunge at prey.*



## TUATARAS

There are just two species of tuatara. They look a lot like iguanas (which are lizards), but tuataras are found only on islands off the coast of New Zealand, coming out of their burrows at night to hunt insects. Tuataras have changed little in the 100 million years since their prehistoric ancestors died out.

Tuatara  
*Sphenodon punctatus*



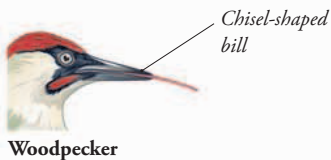


# Birds

There are around 9,700 species of bird. Like mammals, they are warm-blooded vertebrates, but unlike most mammals, they lay eggs, their bodies are covered in feathers, and most can fly.

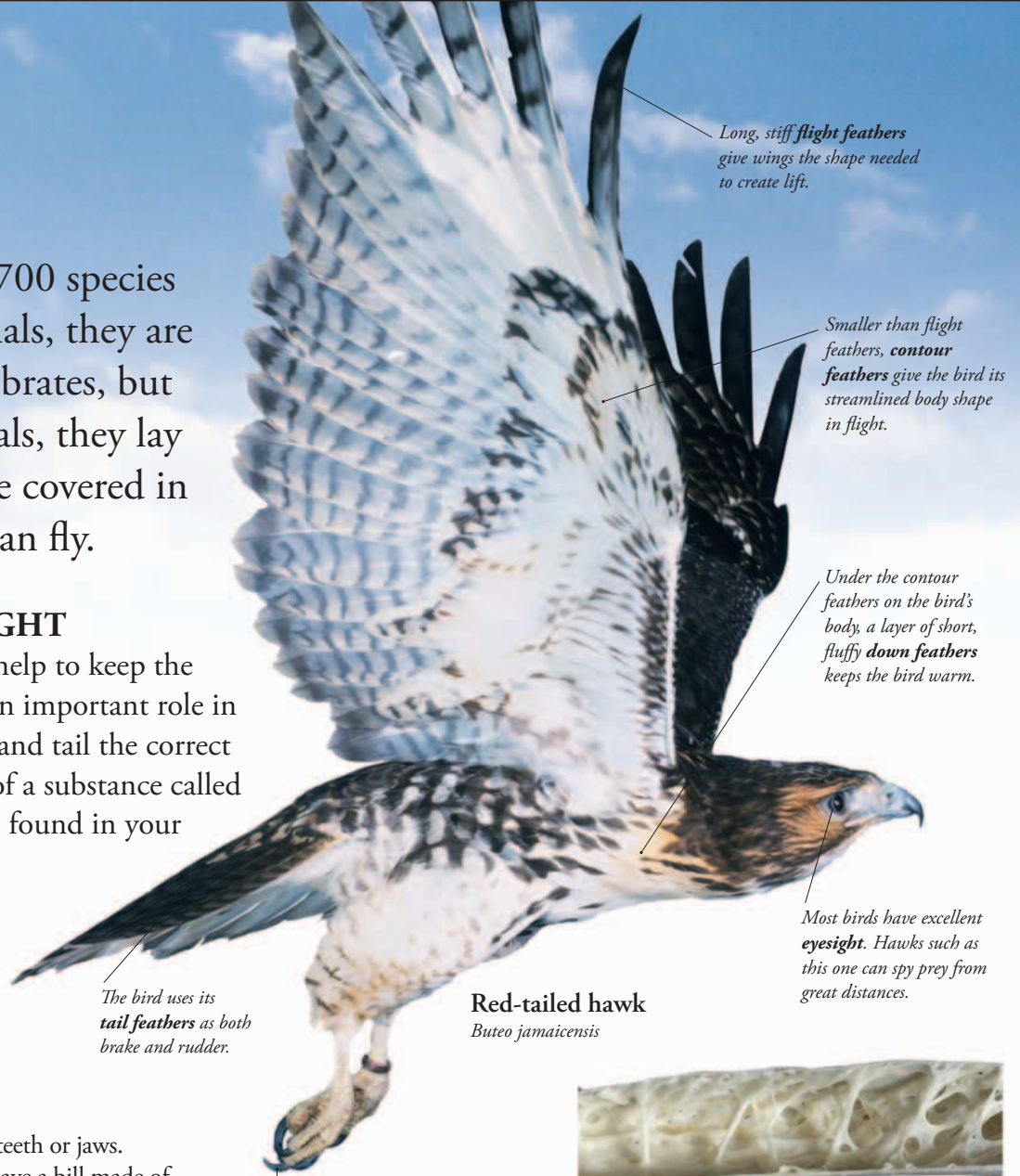
## FEATHERS FOR FLIGHT

A bird's feathers not only help to keep the bird warm, but also play an important role in flight by giving the wings and tail the correct shape. Feathers are made of a substance called keratin—the same protein found in your hair and fingernails.



### Bill shapes

Birds have no teeth or jaws. Instead, they have a bill made of tough, horny keratin. The bill serves many purposes: it can be a deadly weapon for stabbing and tearing, a tool for probing, crushing, or drilling, and a delicate filter. Most birds also use their bills for grooming.



### Bird bones

Most animal bones are filled with spongy marrow, but bird bones are hollow, which makes them light. They are also strong, thanks to the supporting struts inside.

Birds use their **talons** as weapons and to help them grip perches. Water birds have webbed toes to help them swim efficiently.

## FLIGHTLESS BIRDS

Not all birds fly. Flightlessness can be a feature of birds that have few natural predators, such as the New Zealand kiwi. Flying would use a vast amount of energy in very large birds such as ostriches, rheas, emus, and cassowaries. Instead, they invest their energy in running fast. They also grow too large for most predators to tackle.



## WOW!

All birds lay eggs. One reason why is that the female would struggle to fly with a brood of heavy chicks developing inside her. Most birds incubate their eggs by sitting on them. Mother birds usually lay a single egg at a sitting.



## KEEPING ORDER

There are 29 orders of bird, including:

- **Swifts and hummingbirds** These fast flyers have tiny legs and feet.
- **Parrots** There are 352 parrot species, including macaws and budgerigars.
- **Rheas** Flightless rheas have large wings, but weak flight muscles.
- **Waders, gulls, and auks** Puffins are one of 344 species in this varied order.
- **Gamebirds** Peafowl are part of this ground-dwelling order.
- **Flamingos** The only birds that feed with their heads upside-down.
- **Waterfowl** Webbed feet help ducks and other waterfowl to swim.
- **Owls** There are 194 owl species.

## Ruby-throated hummingbird

*Archilochus colubris*



- **Length** 2¼–3½ in (7–9 cm)
- **Wingspan** 3–4 in (8–11 cm)
- **Weight** ⅙–¼ oz (2–6 g)
- **Location** North and Central America

This tiny jewel of a bird uses its specially adapted bill to sip nectar from tube-shaped flowers, while it hovers on wings that beat about 50 times per second. Hummingbirds are among the smallest warm-blooded animals on Earth.



## Hyacinth macaw

*Anodorhynchus hyacinthinus*



- **Length** 3¼ ft (100 cm)
- **Wingspan** 4 ft (130 cm)
- **Weight** 3½–4½ lb (1.5–2 kg)
- **Location** Central South America

This is the world's largest parrot, though the flightless kakapo from New Zealand is heavier. Sadly, it is also one of the rarest of its kind, since it suffered greatly from overcollection for the pet trade. Its habitat has shrunk as loggers and farmers fell its native forests.



LIVING WORLD

## Rhea

*Pterocnemia pennata*



- **Height** up to 40 in (100 cm)
- **Weight** 44 lb (20 kg)
- **Location** South America

Rheas are South America's version of the ostrich. They favor open habitats where they can see trouble coming. A male will mate with several females and care for all the resulting eggs himself, in one large nest.



## Atlantic puffin

*Fratrercula arctica*



- **Length** 12 in (30 cm)
- **Wingspan** 24 in (60 cm)
- **Weight** 16 oz (450 g)
- **Location** High Arctic to the Mediterranean

Puffins are not the best flyers and are awkward on land, too—but they are expert swimmers, hunting fish under water. Outside the breeding season they spend all their time at sea.



## Common peafowl

*Pavo cristatus*



- **Length** Male 6–7½ ft (1.8–2.3 m)  
Female 3¼ ft (1 m)
- **Wingspan** 4½–5¼ ft (1.4–1.6 m)
- **Weight** 8¾–13 lb (4–6 kg)
- **Location** India and Pakistan

The male peafowl (a peacock) is famous for his magnificent tail, which he displays to show off his health and vigor. The female (peahen) has dowdy brown plumage and a short tail. Peafowl eat a varied diet of seeds, flowers, and insects.



## Lesser flamingo

*Phoenicopterus minor*



- **Height** 31½–35½ in (80–90 cm)
- **Wingspan** 3¼ ft (100 cm)
- **Weight** 4½ lb (2 kg)
- **Location** Africa

Colonies of lesser flamingos form a spectacle when they gather in their thousands to breed in the alkaline lakes of the Rift Valley. Each pair produce one egg in a nest of baked mud. Flamingos feed on blue-green algae, which they filter from the water using a specially adapted bill.



## Plumed whistling duck

*Dendrocygna eytoni*



- **Length** 16–23½ in (40–50 cm)
- **Weight** 1–3¼ lb (0.5–1.5 kg)
- **Location** Australia, Indonesia, and Papua New Guinea

The plumed whistling duck is named for the ornate plumage on its flanks (sides), and its distinctive call, which resembles the noise created by blowing air past a blade of grass trapped between two thumbs. It eats grass and weeds.



## Sokoke Scops owl

*Otus ireneae*



- **Height** 6½–7 in (16–18 cm)
- **Weight** 1¼ oz (50 g)
- **Location** Kenya and Tanzania

One of the world's smallest owls, the Sokoke Scops owl specializes in catching beetles and other insects. It hunts by night and hides by day in thickets of scrub. Loss of this habitat means the owl is threatened with extinction.



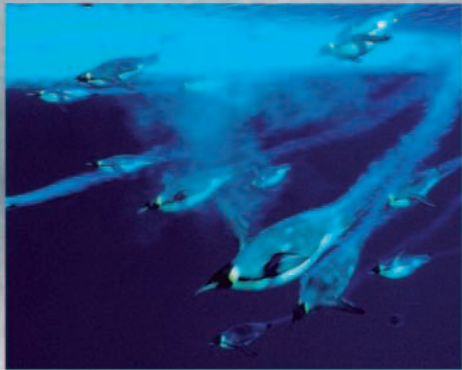


# Penguins

Agile and speedy in the water, penguins more than make up for their inability to fly. These birds hunt fish, krill, and squid in the waters of the southern hemisphere. In the warmer months, they come onto land to breed in large colonies.

## Swimming

Emperor penguins have sleek, streamlined bodies and flattened wings, or flippers, to cut through the water. Dense feathers and a thick layer of blubber keep them warm in the icy Antarctic waters.



## Adélie penguin

*Pygoscelis adeliae*



- **Height** 16–30 in (40–75 cm)
- **Weight** 10–12 lb (4–5.5 kg)
- **Location** Antarctica

One of the smallest and most abundant of all penguins, the Adélie spends most of the winter at sea but then comes ashore in the summer to breed. Mating pairs build nests in large colonies, which offers protection from egg thieves such as skuas (seabirds).

## Huddling

When they are seven weeks old, emperor penguin chicks huddle together in a “creche” to keep warm. The fluffy gray down feathers of the chicks also trap body heat, insulating them from the cold Antarctic winds.



## Yellow-eyed penguin

*Megadyptes antipodes*



- **Height** 26–28 in (66–70 cm)
- **Weight** 12 lb (5.5 kg)
- **Location** New Zealand



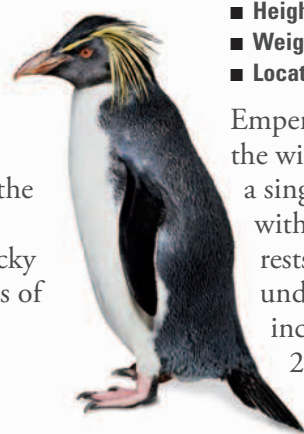
Fewer than 4,000 of these rare penguins live on the islands of southern New Zealand. The striking yellow eye-stripe gives them their common name.

## Rockhopper penguin

*Eudyptes chrysocome*



- **Height** 20 in (50 cm)
- **Weight** 5½ lb (2.5 kg)
- **Location** Sub-Antarctic



These small, crested penguins take their common name from the way they hop as they move around their rocky colonies on the islands of the sub-Antarctic.

## Emperor penguin

*Aptenodytes forsteri*



- **Height** 43 in (110 cm)
- **Weight** 77–88 lb (35–40 kg)
- **Location** Antarctica

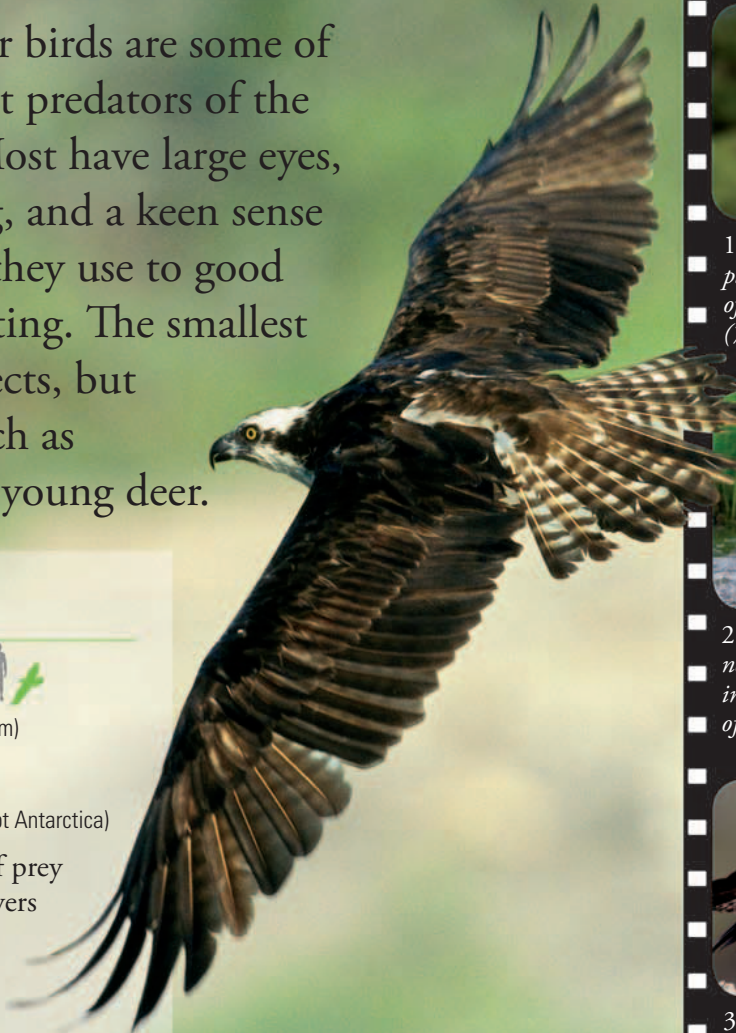


Emperor penguins breed in the winter. The female lays a single egg and leaves it with the male. The male rests the egg on his feet, under his belly, and incubates it for about 2½ months.



# Birds of prey

These spectacular birds are some of the most efficient predators of the animal world. Most have large eyes, excellent hearing, and a keen sense of smell, which they use to good effect when hunting. The smallest species hunt insects, but large raptors, such as eagles, can kill a young deer.



## Osprey

*Pandion haliaetus*



- **Height** 20–23½ in (50–60 cm)
- **Weight** 3¾ lb (1.5 kg)
- **Diet** Fish
- **Location** Worldwide (except Antarctica)

This spectacular bird of prey lives near freshwater rivers and lakes and coastal waters, where it has a plentiful supply of its favorite food: fish.

## MASTER FISHER

The osprey is a skilled hunter, perfectly adapted for catching fish.



1. **EYE IN THE SKY** *The osprey patrols a stretch of water in search of fish, hovering and gliding 230 ft (70 m) or more above the surface.*



2. **GOTCHA!** *The osprey spots a fish near the surface and plunges down into the water, grabbing both sides of its prey with long, curved talons.*



3. **DINNER TIME** *The osprey returns to the nest to feed its young. The male is the main provider of food for the female and her chicks.*

## Peregrine falcon

*Falco peregrinus*



- **Length** 13–20 in (34–50 cm)
- **Weight** 1–3¼ lb (0.5–1.5 kg)
- **Diet** Small birds
- **Location** Worldwide (except Antarctica)

The fastest bird of prey hunts at high speed, reaching a dizzying 220 mph (360 km/h) in a “stoop” (dive).



## Griffon vulture

*Gyps fulvus*



- **Length** 37–43 in (94–109 cm)
- **Weight** 13¾–22 lb (6–10 kg)
- **Diet** Carrion
- **Location** North Africa, southern Europe, and Asia

The Griffon vulture does not kill. It is a scavenger, feeding on carrion (dead animals)—often the leftovers of predatory animals.



## Bald eagle

*Haliaeetus leucocephalus*



- **Length** 28–38 in (71–96 cm)
- **Weight** 6½–14 lb (3–6.5 kg)
- **Diet** Fish, small mammals, birds, and carrion
- **Location** North America

Bald eagles are expert fishers, swooping down to grab fish from the water. They may also steal the catch of another eagle.





# Fish

Fish are the biggest and oldest group of vertebrate. They were the first animals to have backbones, evolving 500 million years ago. There are around 25,000 species of fish, all of which are cold-blooded and have bodies that are adapted to living in water.

Also called the tail fin, the **caudal fin** acts as a paddle, providing "thrust" to propel the fish forward.

The **trunk**, or back end, of the fish is packed with swimming muscles. It's these muscle blocks that make many fish good to eat.

**Dorsal fins** give the fish stability, helping it to make sudden changes in direction and stopping it from rolling from side to side. This fish has two dorsal fins, but other fish might have three separate dorsal fins or just one.

The gas-filled **swim bladder** helps the fish control its buoyancy. By inflating or deflating its swim bladder, a fish can rise up or sink in the water.

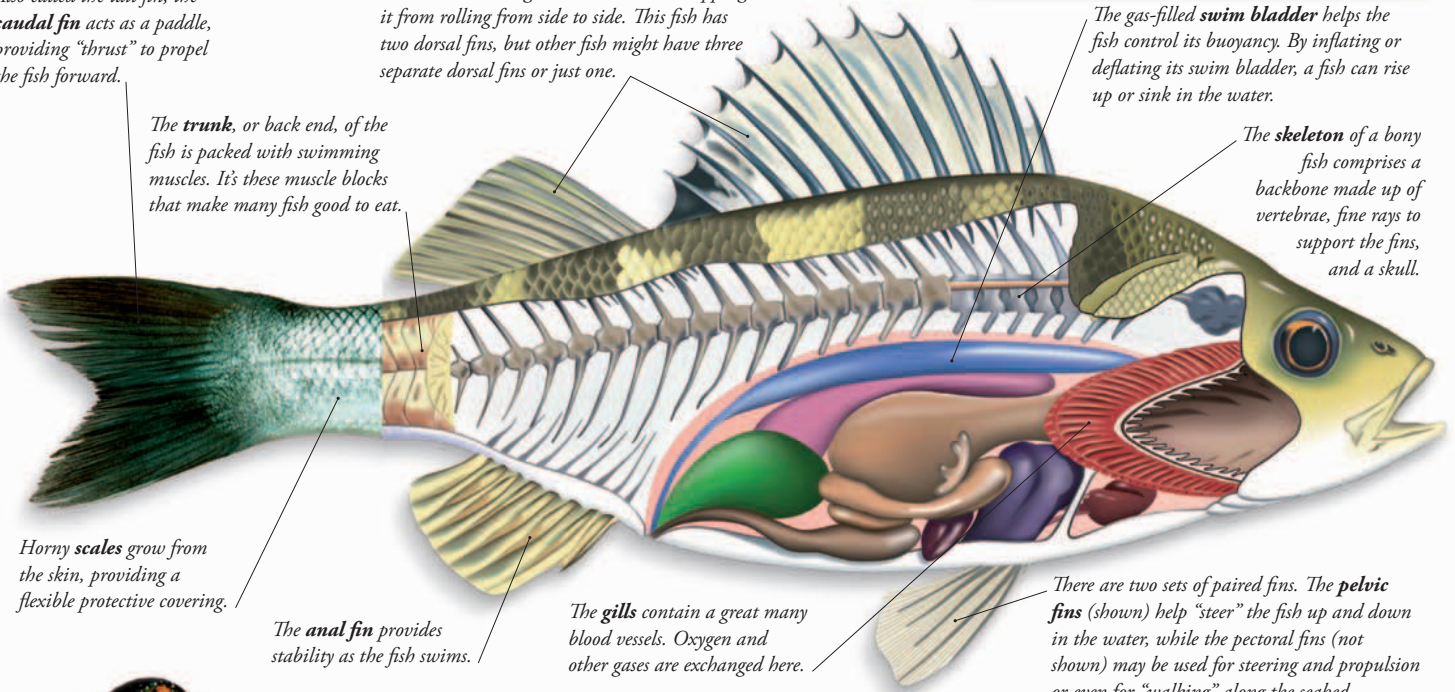
The **skeleton** of a bony fish comprises a backbone made up of vertebrae, fine rays to support the fins, and a skull.

Horny **scales** grow from the skin, providing a flexible protective covering.

The **anal fin** provides stability as the fish swims.

The **gills** contain a great many blood vessels. Oxygen and other gases are exchanged here.

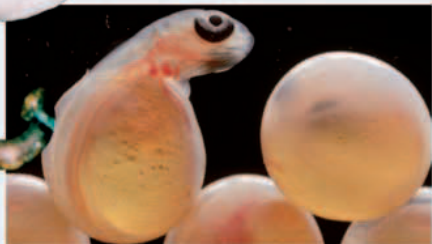
There are two sets of paired fins. The **pelvic fins** (shown) help "steer" the fish up and down in the water, while the **pectoral fins** (not shown) may be used for steering and propulsion or even for "walking" along the seabed.



## REPRODUCTION

◀ **MALE MOM** *Seahorses are unusual in that the female lays her eggs in the male's pouch and he carries the young until they hatch.*

While some fish mate and give birth to live young, most reproduce by releasing eggs into the water. This is called spawning. Often fish will gather at special spawning sites where their young will have the best chance of survival.



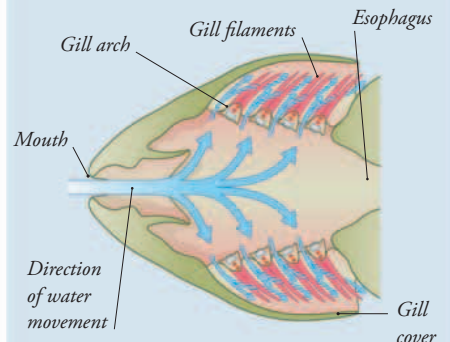
▲ **LARVAE** *Some species hatch as small, fully formed fish, but others hatch as larvae and will change as they grow.*



▲ **SPAWNING** *Many species release vast amounts of eggs at a time, to increase the chances of some surviving.*

## TAKE A LOOK: GILLS

Fish obtain oxygen using their gills. Water is taken in through the mouth, flows over the gills, and out under the gill covers on the sides of the head. Most cartilaginous fish do not have gill covers.





## Blue spotted stingray

*Taeniura lymma*



- **Length** 27 in (70 cm); up to 6½ ft (2 m) incl. tail
- **Weight** Up to 65 lb (30 kg)
- **Depth** Shallow water to 65 ft (20 m)
- **Location** Indian Ocean, western Pacific, Red Sea

This relatively common fish lives around tropical coasts and reefs, where it feeds on mollusks and crustaceans hidden on the sandy seafloor. Like most rays, it “flies” through the water using wavelike movements of its large pectoral fins, which give the body its disk shape. The long tail bears a sting, used in self-defense.



## Common fangtooth

*Anoplogaster cornuta*



- **Length** 6–7 in (15–18 cm)
- **Weight** Unknown
- **Depth** 1,600–16,000 ft (500–5,000 m)
- **Location** Oceans worldwide

Also known as the ogrefish, this ugly-looking fish usually lives at great depths. It detects prey, mainly other fish, using its lateral line organs—lines of pressure-sensitive cells on the sides of its body that pick up vibrations in the water.



## Giant sea bass

*Stereolepis gigas*



- **Length** 8¼ ft (2.5 m)
- **Weight** 880 lb (400 kg)
- **Depth** 15–150 ft (5–45 m)
- **Location** Eastern Pacific, from California to Mexico, and Japan

These huge fish lurk close to kelp-fringed drop offs on the rocky coasts of California, Mexico, and Japan. An individual may live to the great age of 100 years, but the species breed so slowly that losses due to overfishing take decades to make up.



## Clown anemonefish

*Amphiprion ocellaris*



- **Length** 3–4 in (8–11 cm)
- **Depth** Up to 50 ft (15 m)
- **Location** Seas around southeast Asia and northern Australia

These brightly colored little fish live in the shallow sheltered lagoons created by coral reefs. They gain protection from predators by hiding among the tentacles of anemones, which other fish avoid because of their deadly stings. No one knows for sure how anemonefish keep from being stung. Anemonefish begin life as males and change into females once they have reached a certain size.



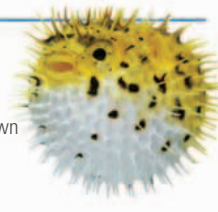
## Puffer fish

*Diodon* sp.



- **Length** 36 in (90 cm)
- **Weight** Exact weight unknown
- **Depth** 6–160 ft (2–50 m)
- **Location** Tropical and subtropical Atlantic, Pacific, and Indian Oceans

When threatened, the puffer fish inflates its body into a spiked ball, making it impossible for all but the largest predators to swallow. But even large predators may avoid eating puffer fish: they not only taste awful, but some are also poisonous.



Inflated



Deflated

## Banded moray eel

*Gymnothorax rueppellii*



- **Length** 32 in (80 cm)
- **Weight** Exact weight unknown
- **Depth** 3–130 ft (1–40 m)
- **Location** Tropical Indian and Pacific Oceans

Like other morays, this species is an aggressive ambush hunter. By day it hides in dark crevices on shallow reefs and at night lurks in the entrance to its lair, waiting to strike at passing fish or shrimp.



## African lungfish

*Protopterus annectens*



- **Length** Up to 6½ ft (2 m)
- **Weight** Up to 38 lb (17 kg)
- **Location** West and Central Africa

Lungfish live in the swamps and backwaters of sluggish rivers, which often dry up completely in the dry season. When this happens, the fish survives up to a year in a cocoon of mud, breathing air with primitive lungs and waiting to emerge with the next rains.



## Red-bellied piranha

*Pygocentrus nattereri*



- **Length** 13 in (33 cm)
- **Weight** 2 lb (1 kg)
- **Location** South America

Famed for their powerful bite and wickedly sharp teeth, these ferocious freshwater fish live in large schools. Their usual prey includes other fish and aquatic invertebrates, although they will attack other animals. Their sensitive hearing and lateral line organs allow them to home in on disturbances caused by struggling prey. Piranhas in turn are hunted and eaten by people.



## Great white shark

*Carcharodon carcharias*



- **Length** Up to 23 ft (7 m)
- **Weight** Can reach over 6,600 lb (3,000 kg)
- **Depth** 0–4,300 ft (0–1,300 m)
- **Location** Oceans worldwide

Probably the most feared fish in the seas, the great white is a predator of large fish, squid, and seals. Great white sharks are protected, since they were overfished in the past.





# Invertebrates

There are thought to be 5 million species of invertebrate roaming the planet—that's 95 percent of all animal life on Earth. They are the world's most successful animals and can be found on land, in the sea, in the air, and even inside your body!

**There is a huge variety of invertebrate.**

The differences lie not just in the way they look, but also in their behavior and even the way they move.

**TAKE A LOOK**

*In addition to no backbones, invertebrates also have no true jaws.*

Earthworm  
Garden snail  
Tenebrionid beetle

**WHAT IS AN INVERTEBRATE?**  
Animals without backbones are called invertebrates. They have no internal skeleton; instead, some have an exoskeleton (a hard outer cover, like a crab or a beetle), some live inside a shell (such as snails and clams), and some are divided into soft segments (such as worms).



▲ SPONGES are invertebrates of the simplest kind: they don't even have a head or a brain...

... Yet octopuses are very intelligent. A female in captivity learned to open jars by copying her keeper.

▲ ANTS are social animals that work together for survival...

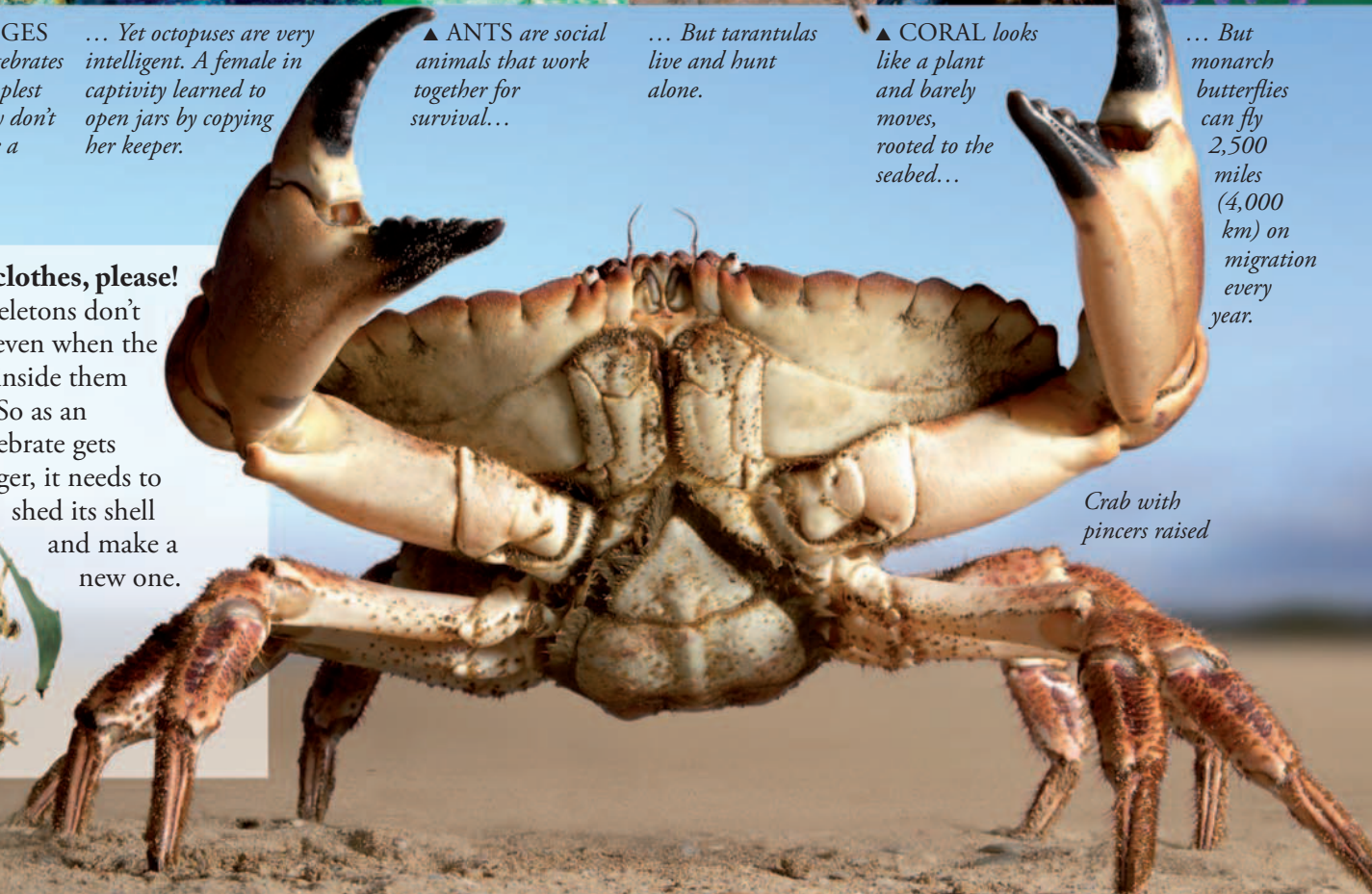
... But tarantulas live and hunt alone.

▲ CORAL looks like a plant and barely moves, rooted to the seabed...

... But monarch butterflies can fly 2,500 miles (4,000 km) on migration every year.

**New clothes, please!**

Exoskeletons don't grow even when the body inside them does. So as an invertebrate gets bigger, it needs to shed its shell and make a new one.



Crab with pincers raised



INVERTEBRATE GROUPS

In a classification tree of the animal kingdom (👁️ p. 84–85), there is no group called invertebrates. There is one called vertebrates (it is part of the chordates phylum and is split into mammals, birds, etc.)—but there are more than 30 different main groups of invertebrate, including:



◀ **MOLLUSKS**—*squid, snails, bivalves* (50,000 species) *Squid, slugs, and oysters are all mollusks. Most mollusks have a shell and a radula—a ribbonlike “tongue” covered in scaly denticles.*



◀ **ECHINODERMS**—*starfish, sea urchins, sea cucumbers* (7,000 species) *Nearly all echinoderms live on the seafloor. They have spiny bodies, which are usually divided into five equal parts.*



◀ **ANNELIDS**—*earthworms, leeches, polychaetes* (12,000 species) *Annelid worms have bodies that are divided into segments.*



◀ **CNIDARIANS**—*jellyfish, corals, hydras* (8,000–9,000 species) *All cnidarians have basic bodies with stinging tentacles, a very simple nervous system, and just one opening: the mouth.*



◀ **ARTHROPODS**—*insects, arachnids, crustaceans* (1,000,000 species) *Arthropods, such as this beetle, have an exoskeleton—a hard outer cover. Their exoskeleton and body are divided into parts.*



◀ **SPONGES** (5,000–10,000 species) *It was once thought that sponges were plants, but they are simple animals. They are fixed to the seabed and filter food from the water as it washes over them.*

**Making sense**

Simple invertebrates, such as sea anemones, have simple senses: they can detect food and reach toward it, and they can sense danger and shrink from it. More advanced invertebrates have superior senses. Flies see lots of images through compound eyes, so they can notice the slightest movement; and grasshoppers have eardrums in their abdomens.

▼ **BUTTERFLIES** can taste with their feet. Chemical sensors on the insect's feet “taste” what it lands on, so it knows if it's standing on something it can drink, such as nectar.

**WITHOUT**

**INVERTEBRATES**, the planet would not survive. Krill (a type of crustacean) form the basis of the food chain in polar seas. Insects such as ants and beetles, and their larvae, help clean up the planet. Other insects, such as bees, are essential for pollination (👁️ p. 90-91).

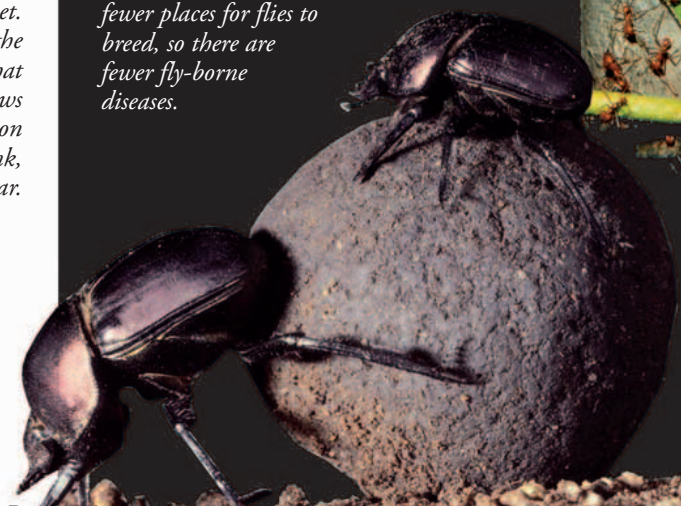


▲ **KRILL**  
*Without krill, entire species of fish would disappear. These tiny creatures form the main part of many marine animals' diets, including the whale shark, the world's biggest fish.*

▶ **ANTS**  
*Decomposers such as ants break up dead animals and plants. The pieces that aren't eaten are more easily absorbed into the ground, releasing nutrients for plants.*

▼ **DUNG BEETLE**  
*Without dung beetles rolling away animal droppings, all kinds of places from African savannas to Australian farmland would be knee-deep in dung. Less dung means fewer places for flies to breed, so there are fewer fly-borne diseases.*

LIVING WORLD





# Amazing arthropods

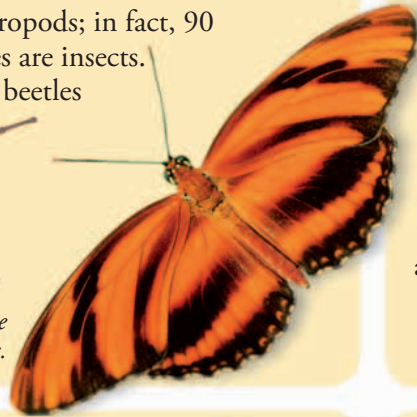
With more than a million species, arthropods make up the largest phylum (main group) in the animal kingdom. They were the first creatures to walk on land, more than 400 million years ago.

**WOW!**

There are as many arthropods on Earth as all other animals put together.

## INSECTS

Insects have three pairs of legs, and a body made up of three parts: a head, a thorax, and an abdomen. This is the biggest group of arthropods; in fact, 90 percent of *all* animal species are insects. Bugs, butterflies, bees, and beetles are all insects.



► WING PATTERNS *help some species to hide and evade predators.*

## ARACHNIDS

Arachnid bodies are made up of two parts. They have four pairs of legs, and two pairs of mouthparts: one set look like legs or claws for grabbing prey, while the other set form pincers or fangs for stabbing and killing. They have no antennae. Spiders, scorpions, ticks, and mites are all arachnids.



► THE IMPERIAL SCORPION *uses its sting in defense and its claws to catch prey.*

## CENTIPEDES AND MILLIPEDES

These arthropods have a long body divided into many segments. Centipedes have one pair of legs per segment and millipedes have two pairs per segment. *Centipede* means “100 feet” and *millipede* means “1,000 feet,” but different species can have between a dozen and 750 legs.



◀ THE GIANT DESERT centipede *has a painful, venomous bite.*



## CRUSTACEANS

Most crustaceans live in water—including crabs, lobsters, shrimp, and barnacles—although woodlice live on land. The species can look very different: a blue lobster grows to 3 ft (1 m) long, but acorn barnacles are a tiny ½ in (15 mm) across.



► LIVE LOBSTERS *range in color, but most are bluish-brown. They turn orangey red when they are cooked.*



## HORSESHOE CRABS

While they look like crustaceans, horseshoe crabs are actually related to arachnids: they have four pairs of legs, two pairs of mouthparts, and no antennae. These animals have scarcely changed in the 300 million years they have existed.



▲ HORSESHOE CRABS *are close relatives to extinct trilobites.*

## SEA SPIDERS

Sea spiders are not spiders at all, although they do have long, spiderlike legs. Most have four pairs of legs, but some have five or six pairs. They have two pairs of eyes.



► SEA SPIDERS *live deep below the waves.*



## SPIDER ATTACK

There are more than 40,000 species of spider, and all of them are venomous. Most are harmless to people—their venom is deadly only to their prey.

### Red-kneed tarantula

*Euathlus smithi*



- **Length** 4 in (10 cm)
- **Legspan** 7 in (18 cm)
- **Prey** Insects, mammals, lizards
- **Location** western central Mexico

The red-kneed tarantula hunts at night. It can sense smells, tastes, and vibrations through the ends of its legs. Females live to 30 years; males live 3–6 years.



▲ **FATAL FANGS** Tarantulas bite into their prey with hollow fangs, injecting potent venom to paralyze their victim.

## BEWARE OF THE SPIDER



**Trapped!** Many spiders do not hunt, but wait for prey to come to them. Using sticky silk spun from a gland in its abdomen, the orb weaver spider creates a web to trap passing insects. The victim is then killed with a deadly bite.



**Do not disturb** Spiders don't usually attack people, but some are dangerous if they are disturbed and bite in self-defense. Mediterranean black widow spiders have enough venom to kill a human. Females usually have the deadliest bite.

### Four-spot orb weaver

*Araneus quadratus*



- **Length** ¼–¾ in (8–17 mm)
- **Legspan** Up to 3 in (7 cm)
- **Prey** Small flying insects
- **Location** Europe and Asia

Orb weavers spin webs in grasses or scrub. Females can change color over several days to camouflage themselves.



### Peacock parachute spider

*Poecilotheria metallica*



- **Length** 2½ in (6 cm)
- **Legspan** 7 in (18 cm)
- **Prey** Insects, baby birds, lizards
- **Location** Southern India

This spider is also known as the Gooty sapphire because of its blue coloring. While females live to 12 years, males live only 3–4 years. It is very rare and faces extinction because of habitat loss.



### Fen raft spider

*Dolomedes plantarius*



- **Length** Females ½–1 in (17–22 mm)  
Males ½–¾ in (13–18 mm)
- **Legspan** Up to 3½ in (9 cm)
- **Location** Europe

This spider uses its feet to sense the movement of prey in pools of water—then it runs across the water to catch it.





# Incredible insects

Insects are the most successful animals on Earth. There are more than one million known species, but scientists think there may be millions more still to be discovered. Many other life-forms rely on insects: most plants use them as pollinators, and lots of animals are insect-eaters.

## TELL ME MORE...

An insect's body is made up of three parts: the head, thorax, and abdomen. These parts are linked by the exoskeleton, the circulatory system, soft tissue, and nerves, which control the insect's body functions.



The **thorax** is packed with muscle to power the legs and wings.

The **head** contains sense organs such as eyes and antennae.

The **abdomen** contains most of the digestive system and the reproductive system.

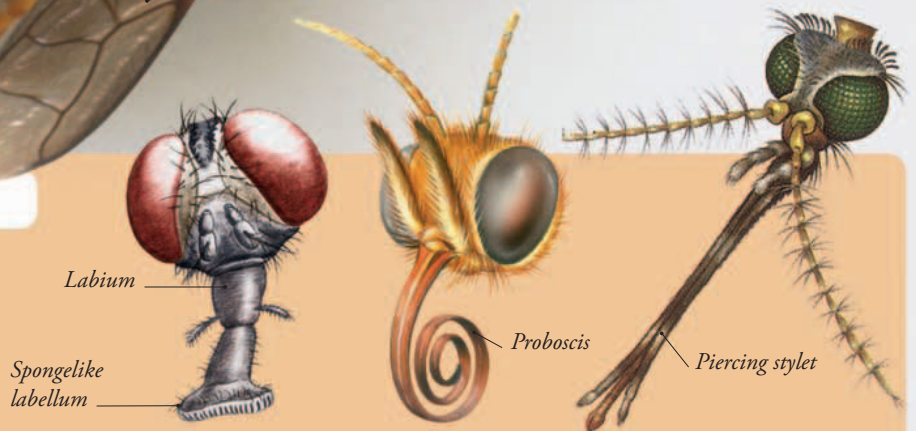
Insects have one pair of **antennae**, or feelers, which they use to explore their environment. Insects use their feelers in many different ways: to touch, smell, taste, and even hear (by picking up vibrations in the air).

Adult insects respire (breathe) by taking in air through **spiracles**—openings along the thorax and abdomen.

Most insects have two pairs of **wings**. In this wasp the front and hind wings are linked. In beetles and many bugs the front wings form hard cases called elytra, which protect the softer hindwings below.

## TAKE A LOOK: INSECT MOUTHS

Different types of insect eat very different foods, and so the mouthparts of each species are suited to different styles of feeding. Some insects have jaws shaped into pincers to kill their prey, or tiny clippers for cutting plant leaves. In many other insects the jaws are replaced by other specialized mouthparts.



Labium

Spongelike labellum

Proboscis

Piercing stylet

▲ **SPONGER** Flies soak up liquid foods through a spongy tube.

▲ **SUCKER** Butterflies uncurl their long, thin proboscis to use as a straw for sucking up nectar.

▲ **STABBER** Mosquitoes have needle-sharp stabbing mouthparts for piercing skin and sucking up blood.



## LADYBUG LIFECYCLE

**1. EGG LAYING** *Insects reproduce by laying eggs. After mating, a female ladybug lays her eggs on a leaf. About a week later, the larvae emerge.*

**2. HATCHING** *The larvae look nothing like their parents! They have a soft body covering, called a cuticle, which soon hardens and turns dark.*

**3. GROWING** *The larva must eat lots of food to grow. Over about four weeks it will kill and eat hundreds of sap-sucking aphids.*

**4. PUPATING** *When the larva is ready to pupate, it fixes itself to the underside of a leaf and sheds its skin, revealing a soft cuticle underneath. This "pupal cuticle" takes about a week to turn hard and dark. The larva does not move during this time.*

**5. EMERGENCE** *A week later, the pupal cuticle splits open and a new adult ladybug crawls out. To begin with, its body and wing cases are soft and lack the typical bright color and spots.*

**6. ADULT** *The new adult's wing cases expand and harden into a protective shield. The color darkens and the distinctive ladybug spots appear. The cycle can now begin again.*

## Warning colors

Many insects protect themselves from predators by storing toxins in their bodies. They then warn predators by displaying bright colors, usually red, orange, or yellow.

Monarch and viceroy butterflies, which look similar, both benefit from a color and pattern that say "I taste really bad!"

## INCREDIBLE INSECTS

Monarch  
*Danaus plexippus*



Viceroy  
*Limenitis archippus*

## Insect camouflage

Another great way of avoiding being eaten is to make yourself invisible. Many insects are masters of disguise, able to hide in full view of predators by blending in perfectly with their background. Can you spot this moth?



Rustic sphinx moth *Manduca rustica*

## IS IT A BEE OR WASP?

There are many differences between these similar-looking insects.

- There are about 20,000 bee species.
- Social bees live in colonies in nests made of beeswax.
- Bees feed on nectar and pollen from plants.
- Bees have hairier bodies than wasps.
- A bee can sting only once—the sting is ripped out of the bee's abdomen and left behind in the victim. The bee will die soon after.
- There are around 75,000 species of wasp.
- Social wasps live in nests made out of paper, which they make by chewing wood.
- Wasps eat other insects.
- Wasps are more brightly colored than bees.
- A wasp's sting can be used many times. Like bees, only females have a stinger. It is adapted from her ovipositor—the tube through which she lays her eggs.



Bees feed on nectar...



... but wasps eat other insects.



# Bugs *and* beetles

The word “bug” is often used to mean any creepy-crawly, but it is actually an order of a particular kind of insect. This order is called *Hemiptera*, and it has 82,000 species. Beetles are not the same as bugs: they have their own order, *Coleoptera*. There are 370,000 beetle species—that’s one-third of all known insect species.



Lantern bug  
*Phrictus quinquepartitus*

## BUGS



Cotton stainer bug  
*Dysdercus decussatus*



Cicada  
*Angamiana aetherea*



Giant water bug  
*Lethocerus grandis*

**WOW!**

All the insects you see here are life-size. The giant water bug is the world’s longest bug, but it’s dwarfed by the Hercules beetle.



Assassin bug  
*Eulyes illustris*



Water scorpion  
*Nepa* sp.



Squash bug  
*Coreus marginatus*



Bed bug (magnified x 2)  
*Cimex lectularius*



Leaf hopper  
*Cicadella viridis*



Bugs have two pairs of wings and a beaklike mouth for piercing and sucking up food.

◀ A stink bug preys on a caterpillar.

## HOW CAN YOU TELL IF IT'S A BUG?



Lacewing nymph



Adult lacewing

Bugs have incomplete metamorphosis: they start life as nymphs that look similar to the adult form, but without wings or reproductive organs.



BEETLES



Weevil  
*Eupholus bennetti*



Leaf beetle  
*Calligrapha dislocata*



Seven-spotted ladybug  
*Coccinella septempunctata*



Ten-spotted ground beetle  
*Thermophilum decempunctatum*



Stag beetle  
*Lucanus cervus*



Tortoise beetle  
*Eugenysa regalis*



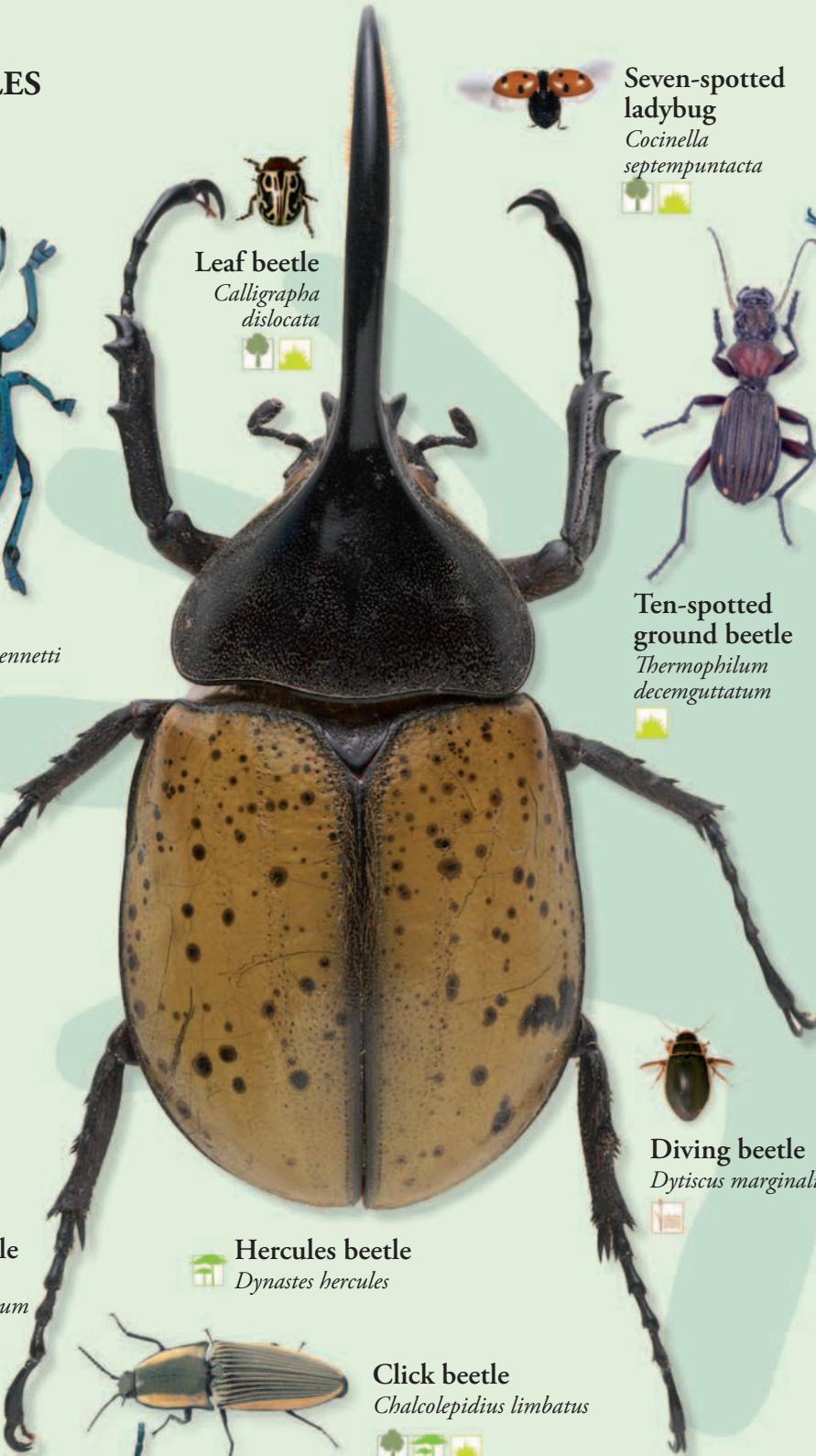
Shining fungus beetle  
*Scaphidium quadrimaculatum*



Diving beetle  
*Dytiscus marginalis*



Giant harlequin beetle  
*Acrocinus longimanus*

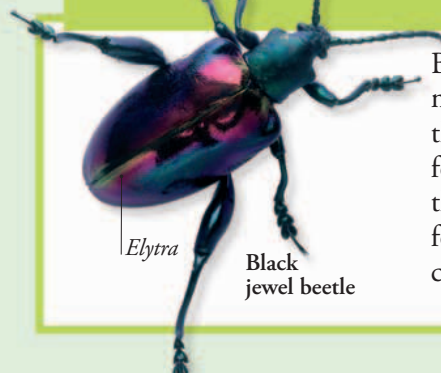


Hercules beetle  
*Dynastes hercules*



Click beetle  
*Chalcolepidius limbatus*

HOW CAN YOU TELL IF IT'S A BEETLE?



Elytra  
Black jewel beetle

Beetles have elytra that meet in the middle of the body. Elytra are hard forewings that fold over the soft hindwings, forming a protective case.

Beetles have complete metamorphosis: they start life as a larva, then change to a pupa, and finally become an adult. Larva and pupa look different from the adult.



Stag beetle larva...

... pupa... ... and adult



# Marine invertebrates

Huge numbers of invertebrates live in the sea. Some, such as corals and sponges, live fixed to the spot, but others, including jellyfish and squid, drift in midwater. Starfish and crabs creep and scuttle on the seabed everywhere from sunlit shallows to pitch black depths.

## OCTOPUS ANATOMY

Octopuses belong to a group of mollusks called cephalopods, thought to be the smartest of all invertebrates. Some cephalopods have an external shell, but in others the shell is internal. Most of an octopus's organs are inside its head, including its digestive system and gills.

► **OCTOPUSES** generally crawl on the seabed, but also use arm movements and a form of jet propulsion to swim in open water.

### TAKE A LOOK: COLORFUL CHARACTERS

Octopuses can change color rapidly, adopting different patterns to communicate emotions and to camouflage themselves on the seafloor to avoid predators. If the camouflage doesn't work, they squirt out a jet of ink. Hidden in the cloud, they can escape from danger.



▲ **ESCAPE** An octopus releases ink over a potential threat.

## Day octopus

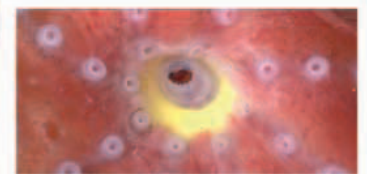
*Octopus cyanea*



- **Size** Body: 6¼ in (16 cm); arms 32 in (80 cm)
- **Location** Indo-pacific region

Unlike most other octopuses this animal hunts by day, using changing body patterns to disguise itself. Its preferred foods include clams, shrimp, crabs, and fish.

The octopus's eight arms bear rows of suckers that grip onto rocks—and also onto prey.



▲ **MOUTH** The octopus's mouth is a stretchy circular opening. Inside is a sharp beak made of horn, used for tearing up prey.



## Red general starfish

*Protoreaster linckii*



- **Diameter** Up to 12 in (30 cm)
- **Location** Indian Ocean

Like most starfish, the red general is a slow-moving predator. It creeps over reefs and rocks on hundreds of tiny, suckered, tube feet, hunting small clams, tubeworms, sponges, and other fixed invertebrates. It feeds by covering the prey with its body and pushing its stomach out through its mouth (in the middle of the star).



## Horned ghost crab

*Ocyrode ceratophthalmus*



- **Width** 2½-3 in (6-8 cm)
- **Location** Indian and Pacific Oceans

Ghost crabs live on sandy beaches, where they feed on organic matter washed up by the tide. They scuttle and burrow at such speed that they sometimes seem to disappear.



## Yellow tube sponge

*Aplysina fistularis*



- **Height** Up to 24 in (61 cm)
- **Location** Tropical seas

Sponges are among the simplest of animals. Yellow tube sponges have a chimney-shaped body supported by a flexible skeleton made of protein. Some other species may have more rigid skeletal parts. Water is drawn in through pores in the tube.



## Sea slug

*Chromodoris kuniei*



- **Length** 2 in (5 cm)
- **Location** Western Pacific Ocean

Sea slugs, also known as nudibranchs, are shell-less relatives of snails. They are carnivorous and hunt by gliding through coral reefs in search of prey that cannot escape, such as sponges, barnacles, and corals.



## European lobster

*Homarus gammarus*



- **Length** 24-40 in (60-100 cm)
- **Location** European coasts

This powerful cousin of shrimp and crabs lurks in rocky lairs by day, emerging at night to hunt smaller invertebrates and fish using its sensitive antennae and large claws. Like other crustaceans, lobsters must shed their rigid body armor in order to grow.



## Elkhorn coral

*Acropora palmata*



- **Size** Up to 10 ft (3 m) across
- **Location** Caribbean Sea

This brittle structure is not a single animal, but a colony of thousands, all growing on a stony base that they build themselves. Each tiny coral animal, or polyp, has a simple bag shape, with a mouth at the top surrounded by tiny tentacles.



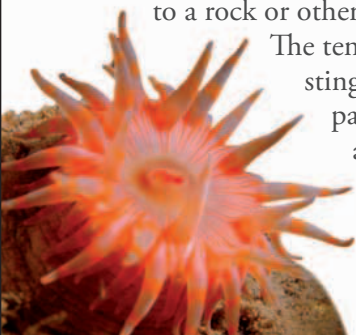
## Dahlia anemone

*Urticina felina*



- **Width** 10-14 in (25-35 cm)
- **Location** Northern hemisphere coastal waters

The dahlia anemone's colorful, flowerlike body grows attached to a rock or other hard surface. The tentacles bear tiny stinging cells that paralyze small animals. Food caught this way is passed to the mouth.



## Lion's mane jellyfish

*Cyanea capillata*



- **Width** Up to 6½ ft (2 m)
- **Location** Cool northern seas

Named for the mass of brown frills on its central arms, the lion's mane jelly is common in northern seas and is often washed ashore in storms. Jellyfish lack any kind of brain, but their simple design has been successful for 500 million years.





# What are you doing here?

Birds that can't fly and reptiles that appear to; snakes that live in the sea and fish out of water... Sometimes animals just don't seem to behave how you might expect them to!

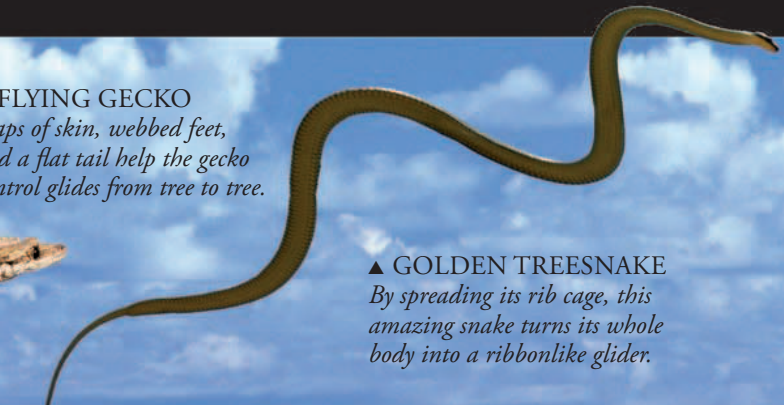
## AIR

Only birds, bats, and insects are capable of true flight, but several other kinds of animal have developed the ability to control long glides through the air.

▼ **FLYING GECKO**  
*Flaps of skin, webbed feet, and a flat tail help the gecko control glides from tree to tree.*



▲ **GOLDEN TREESNAKE**  
*By spreading its rib cage, this amazing snake turns its whole body into a ribbonlike glider.*



## LAND

Sometimes life on land is the best option even for animals you would normally expect to see in the air or under water.

◄ **EMU**  
*The Australian emu has huge, powerful legs, but no wings.*



## SURFACE OF WATER

The surface of water is an important barrier for most animals, but some species use it to their advantage to escape predators or to surprise unwary prey.

▲ **FLYING FISH**  
*Flying fish skim over the waves at up to 37 mph (60 km/h), but predators cannot follow.*



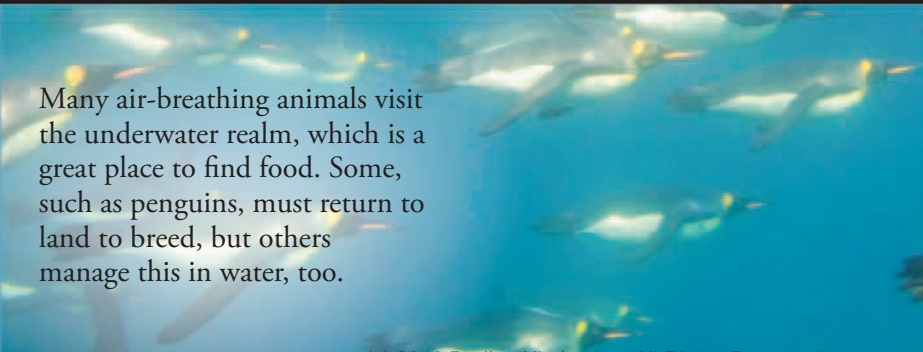
◄ **BASILISK LIZARD**  
*Big feet and amazing speed allow this reptile to sprint over still water.*



## UNDERWATER

Many air-breathing animals visit the underwater realm, which is a great place to find food. Some, such as penguins, must return to land to breed, but others manage this in water, too.

▼ **PENGUINS**  
*Penguins gave up flight but have perfected the art of swimming under water.*







TAKE A LOOK: FROM SEA TO TREE

The coconut crab is the largest arthropod on land. It is a confident but careful climber and can climb up palm trees to collect fresh coconuts. It will crack these open with its huge claws to get to the flesh inside.



Coconut crab *Birgus latro*

A DIFFERENT APPROACH

We're used to seeing certain animals in particular places, but in the struggle for life, many animals find that they can gain an advantage by exploiting a completely different environment. They may have developed their extraordinary behavior as a way of finding food, of escaping predators, or simply to stay alive.



◀ FLYING SQUIRREL

*A flap of skin along the squirrel's flanks acts as a controllable parachute.*



◀ FLYING FROG

*Long, strong toes support webs of skin on the flying frog's umbrellalike feet.*



◀ CASSOWARY

*The forest-dwelling cassowary uses its big feet for running and fighting.*



◀ MUDSKIPPER

*The mudskipper crosses mud flats using its fins to drag its body over the sand.*

UNDERGROUND

Many animals spend at least part of their lives underground, where there are few predators. Some animals survive unfavorable conditions such as droughts by hibernating underground.



◀ PERIODICAL CICADA

*Periodical cicada larvae spend their early lives underground before emerging all together after 13 or 17 years.*

▶ AFRICAN LUNGFISH

*When tropical rivers dry up, these amazing fish burrow and survive by breathing air in a small damp chambers in the hard baked mud.*



◀ WATER SPIDER

*Hairs on the water spider's body trap air, which the spider breathes while under water. It's just like diving with an air tank.*



▶ MANATEE

*These gentle vegetarians live and breed in shallow tropical seas.*

◀ SEA SNAKE

*Sea snakes spend their whole lives in water and are often seen hundreds of miles from land.*





# Microlife

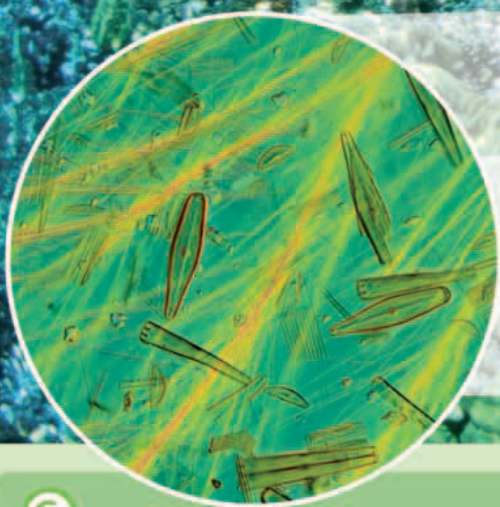
Some living things, such as elephants and oak trees, are difficult to miss if you're standing next to one, but others are much harder to see. There are thousands of species of microscopic organism living in the air, on land, and in water all around you, and on your body, too!

## WHAT'S IN THE WATER?

In addition to fish and other marine creatures, our oceans, rivers, and lakes are teeming with plankton—microscopic life that drifts with the current. Plankton includes tiny animals (zooplankton) and plantlike life-forms (phytoplankton). Many creatures eat plankton, and in this way whole aquatic ecosystems depend on it.



◀ KRILL are tiny crustaceans that eat plankton. Large marine animals, including whales, feed on the krill, making them a vital link in the food chain.



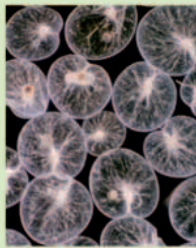
◀ ALGAE Most phytoplankton is made up of algae. Many algae are made up of just one cell, like these diatoms.

## TAKE A LOOK: ALGAE

Single-celled algae belong to a group of organisms known as protists. Like plants, these algae make food from sunlight, using a process called photosynthesis (👁️ p. 87).



◀ BLOOMING Algal blooms are a sign of nature out of balance. The bloom blocks sunlight, uses up nutrients, and starves or poisons other plants and animals.



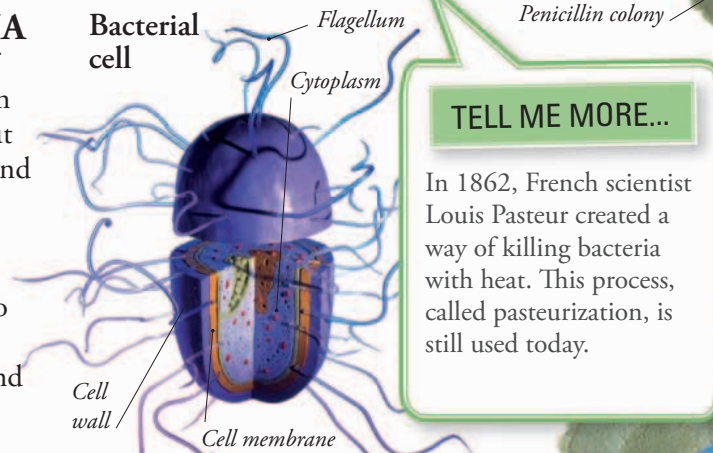
◀ GLOWING Several algae are bioluminescent: they give out light when they are disturbed. This alga, Noctiluca, can make the sea glow an eerie green.





## BRILLIANT BACTERIA

Bacteria are an essential part of life on Earth. Some types live in soil and release nitrates, without which plants would not grow and the food chain would collapse. Other types live in your intestines, helping you digest your food. But bacteria can also be harmful, causing dangerous diseases in all kinds of plants and animals, including people.



### TELL ME MORE...

In 1862, French scientist Louis Pasteur created a way of killing bacteria with heat. This process, called pasteurization, is still used today.

### ▲ POWERFUL PENICILLIN

If you have an illness, your doctor might give you penicillin. This is an antibiotic—a medicine that kills bacteria. In 1928, scientist Alexander Fleming found a dish of bacteria with a type of mold growing on it. Where the mold grew, the bacteria had died. From this discovery, Fleming developed penicillin.

▼ CRAB LARVA *Many animals start life as microscopic larvae. Crab larvae find a place to settle as a tiny crab, where they can then grow to be an adult.*



◀ GROWING *Noctiluca algae are also responsible for "red tides." These are usually caused, for example, by sewage or fertilizer. Algae growing in this way can kill other life-forms.*

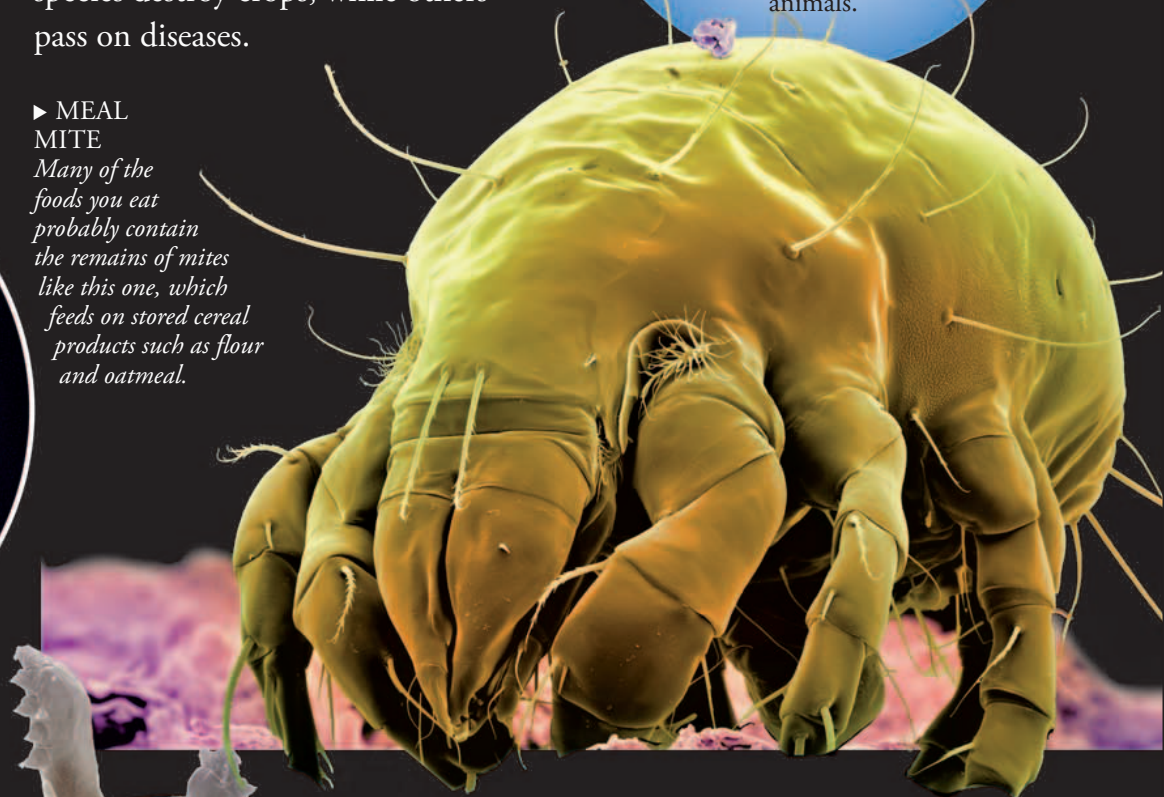


## MINI MONSTERS

Ticks and mites belong to the same class of invertebrate as spiders, the arachnids. They are parasites, living and feeding on plants or other animals, known as hosts. Some species destroy crops, while others pass on diseases.

▶ MEAL MITE *Many of the foods you eat probably contain the remains of mites like this one, which feeds on stored cereal products such as flour and oatmeal.*

**WOW!**  
There are around 30,000 species of tick and mite, most of which are less than  $\frac{1}{32}$  in (1 mm) long. They can be found in stored food such as flour and cheese; in animal dung; and skin, hair, and fur. They feed on plants and on the skin and blood of host animals.



### Eyelash mites

You won't be able to see them or feel them, but living on your face are tiny,  $\frac{1}{1,000}$  in- (0.2 mm-) long mites called *Demodex folliculorum*. The mites cling to eyelashes, to feed on dead skin cells at the eyelash roots—but don't worry, they are harmless.

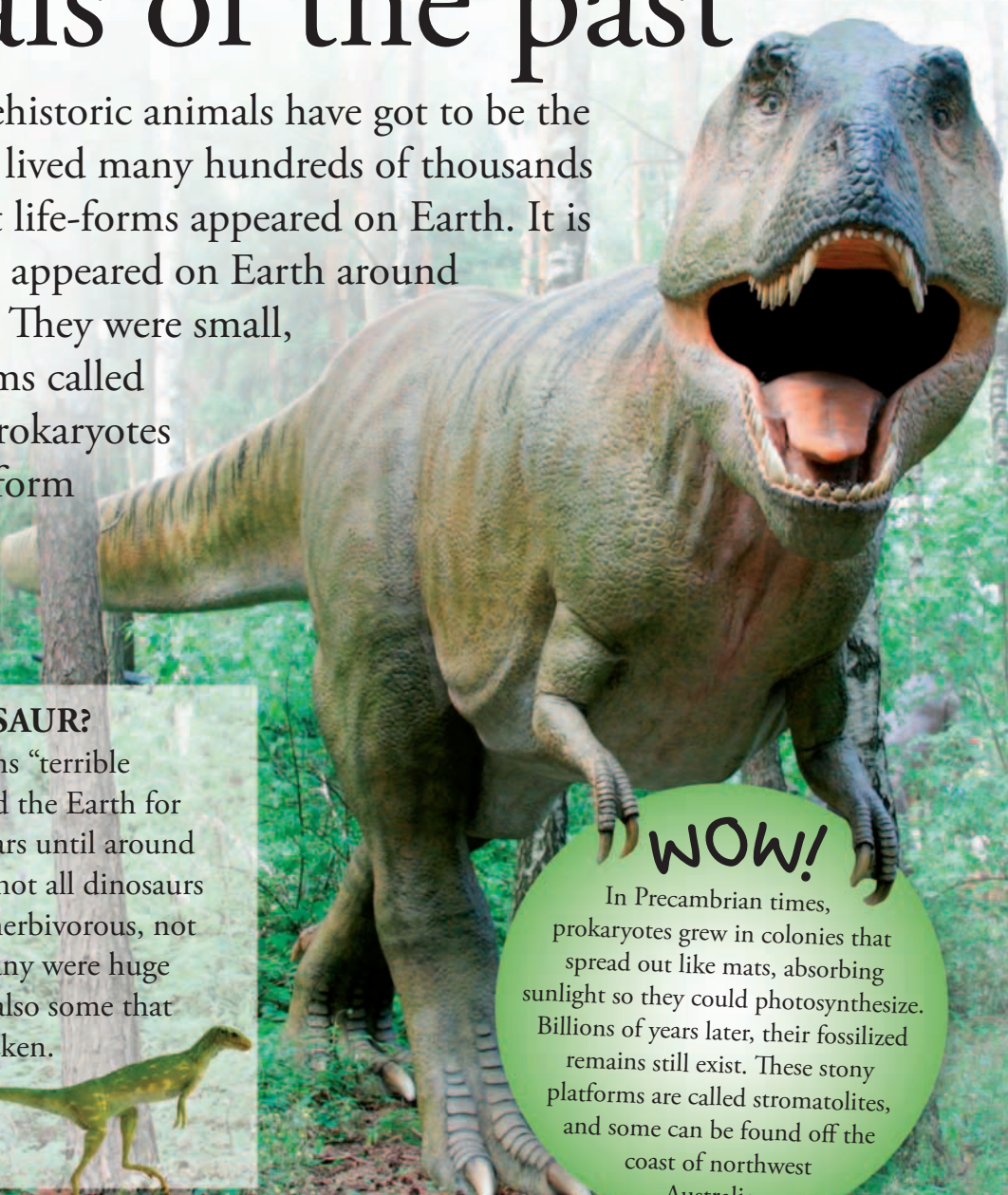
▼ A DUST MITE *can fit on the tip of a needle. This tiny creature eats fragments of dead skin and hair found in house dust.*





# Animals of the past

The most famous prehistoric animals have got to be the dinosaurs—but they lived many hundreds of thousands of years after the first life-forms appeared on Earth. It is thought that life first appeared on Earth around 3.8 billion years ago. They were small, single-celled organisms called prokaryotes. Some prokaryotes survive today in the form of cyanobacteria.

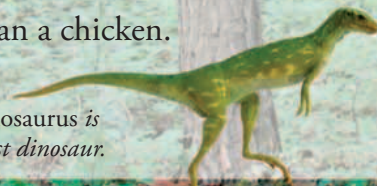


## WHAT WAS A DINOSAUR?

The word “dinosaur” means “terrible lizard.” These reptiles ruled the Earth for more than 160 million years until around 65 million years ago. But not all dinosaurs were terrible: many were herbivorous, not carnivorous, and while many were huge and ferocious, there were also some that were no bigger than a chicken.

### ► DINKY DINOSAUR

*The plant-eating Lesothosaurus is thought to be the smallest dinosaur.*



**WOW!**

In Precambrian times, prokaryotes grew in colonies that spread out like mats, absorbing sunlight so they could photosynthesize. Billions of years later, their fossilized remains still exist. These stony platforms are called stromatolites, and some can be found off the coast of northwest Australia.

## TIMELINE OF PREHISTORIC LIFE

*History is divided into different periods of time.*

*MYA = million years ago.*

**PRECAMBRIAN**  
4.6 BYA–545 MYA

The first forms of life appeared on Earth: simple, single-celled prokaryotes.



**CAMBRIAN**  
545–490 MYA

The first multicelled and hard-bodied life developed, including mollusks and arthropods such as trilobites.



**ORDOVICIAN**  
490–445 MYA

The first crustaceans and jawless fish evolve.



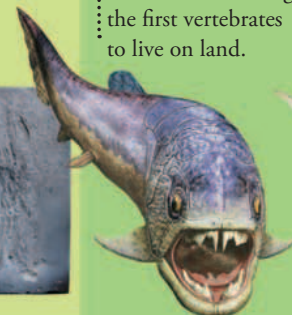
**SILURIAN**  
445–415 MYA

Evolution of the first fish with jaws, and giant sea scorpions—the ancestors of modern arachnids.



**DEVONIAN**  
415–355 MYA

The “Age of Fishes,” when fish diversified rapidly. The first amphibians evolved from fish, becoming the first vertebrates to live on land.



**CARBONIFEROUS**  
355–290 MYA

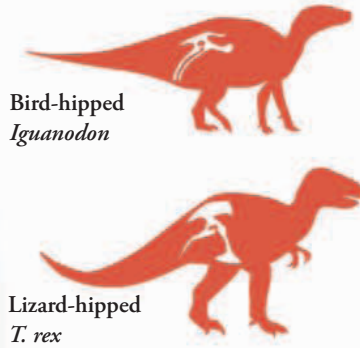
Flying insects and amphibians lived in swampy forests during this warm period, but reptiles ruled the land.





## HIP, HIP

There were two types of dinosaur, classified by the shape of their hip bones: bird-hipped (ornithischians), and lizard-hipped (saurischians). Birds actually evolved from the lizard-hipped dinosaurs. (👁️ p. 244.)



### FAST FACTS

- Scientists that study the history of life on Earth are called paleontologists.
- The term “dinosaur” only refers to a certain type of land-based reptile. Those that flew or lived in the sea are not dinosaurs, but different reptiles.
- There are about 700 named dinosaur species.
- The first dinosaur fossils were *Iguanodon* teeth and bones, found in England in the 1820s.
- The first complete dinosaur skeletons were of 32 *Iguanodons*, found in a coal mine in Belgium in 1878.
- The first dinosaur to be named was the *Megalosaurus*, in 1824.
- The oldest dinosaur fossils discovered to date are 230 million years old.

LIVING WORLD



Fossil of a *Pterodactylus*

### What is a fossil?

Paleontologists use fossils to figure out what early life-forms would have looked like. Most fossils form when the remains of an animal or plant get buried in sediment (sand or mud). Over time, the remains are replaced by minerals in the sediment, which keep the shape of the animal or plant.

## *Tyrannosaurus rex* “King of the tyrant lizards”

- **Length** 39 ft (12 m)
- **Time** Late Cretaceous
- **Fossil location** North America

Like all life-forms, dinosaur species have scientific names, which are written in Latin. The name may reflect what the species looked like, or a characteristic—as with *T. rex*, one of the largest and fiercest meat-eating dinosaurs.



## *Dimorphodon* “Two-form tooth”

- **Wingspan** 4–8 ft (1.2–2.5 m)
- **Time** Early Jurassic
- **Fossil location** Europe and North America

*Dimorphodon* was not a dinosaur, but a pterosaur—a flying reptile. It had an enormous skull and differently sized teeth in its bill—large, pointed teeth at the front, and small teeth at the back. It ate fish, insects, and small animals, but no one knows if it caught its prey while flying or standing on all fours.



## *Dimetrodon* “Two types of teeth”

- **Length** up to 11½ ft (3.5 m)
- **Time** Early Permian
- **Fossil location** Europe and North America

*Dimetrodon* was a sail-backed synapsid. The sail probably helped it warm up and cool down. Synapsids were cold-blooded and scaly like reptiles, but they are actually the ancestors of mammals.



**PERMIAN**  
290–250 MYA

Sail-back synapsids appeared.

**TRIASSIC**  
250–200 MYA

The first dinosaurs, early mammals, turtles, and frogs appeared.

**JURASSIC**  
200–140 MYA

The first bird, *Archaeopteryx*, evolved from the dinosaurs.

**CRETACEOUS**  
140–65 MYA

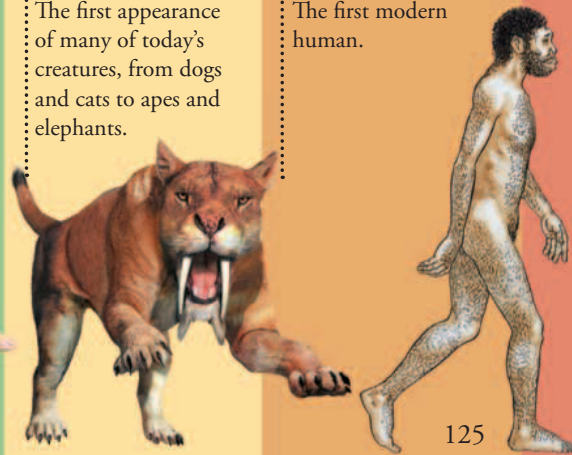
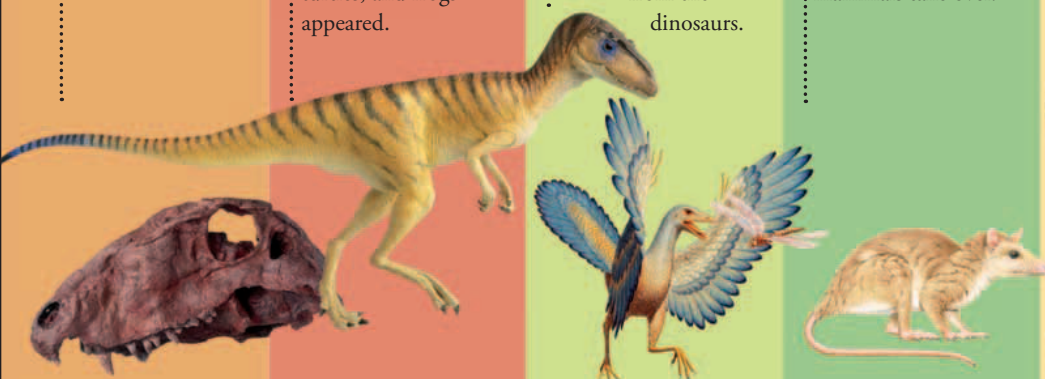
Dinosaurs die out. The first modern mammals take over.

**TERTIARY**  
65–1.6 MYA

The first appearance of many of today’s creatures, from dogs and cats to apes and elephants.

**QUATERNARY**  
1.6 MYA TO PRESENT

The first modern human.





# CONTINENTS of the WORLD

- People naturally inhabit all continents except one: Antarctica.
- The Arctic is not a continent because it is not solid land—it is mostly frozen sea.
- Asia, the biggest continent, stretches from the Arctic circle to the equator.
- North and South America were named after the Italian explorer Amerigo Vespucci.
- Africa contains 53 countries (including islands)—more than any other continent.



At what event  
does a cowboy  
test his skills?

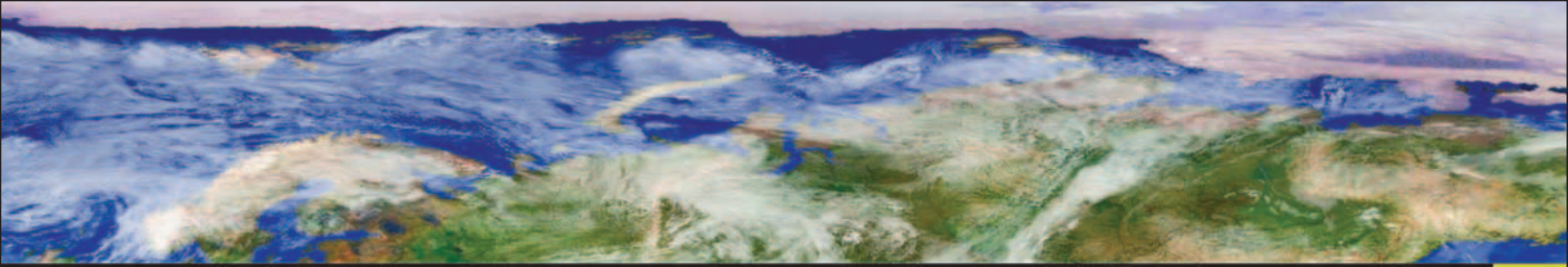
*Find out on pages  
132—133*



Which  
countries  
are the richest in  
the world?

*Find out on pages  
144—145*





*Definition:* The continents are Earth's major landmasses. There are seven continents: North America, South America, Africa, Europe, Asia, Australasia, and Antarctica.



- Europe holds the world's smallest country: Vatican City, Italy, is  $\frac{1}{5}$  sq mile (.44 sq km).
- South America's largest country, Brazil, covers more than half the continent's area.
- When the Earth first formed, all the continents were joined into one big one.
- There are areas of desert on all seven of Earth's continents.
- Aside from Antarctica, Australasia is the most sparsely populated continent.



**?** In what mountain range would you find llamas?  
*Find out on pages 136—137*

**?** Where in the world does classical dancing look like this?  
*Find out on pages 148—149*



# Our world

Just one-third of the Earth's surface is land; the rest is covered by water. The land is divided into seven vast landmasses (continents): North America, South America, Europe, Asia, Africa, Australasia, and Antarctica.



▲ EARTH A night map shows those parts of the world with plentiful electricity supplies.




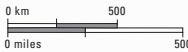


**FAST FACTS**

- World population 6,756 million (January 2009)
- Independent countries 193
- Dependent territories 50
- Continents 7
- Oceans 5
- Largest continent Asia
- Smallest continent Australasia



**KEY TO MAPS**

- Capital city
  - State city
  - State border
  - Coast line
  - River
  - ▲ Mountain
-  North compass  
 Scale  
 Note: Only main languages are given.

CONTINENTS OF THE WORLD







# North America

Stretching from the Arctic Circle to the tropics, North America is the third-largest continent.

Two countries, Canada and the United States, take up three-quarters of the continent, which also includes Mexico, seven Central American countries, and the Caribbean Islands.



## NORTH AMERICAN FACTS

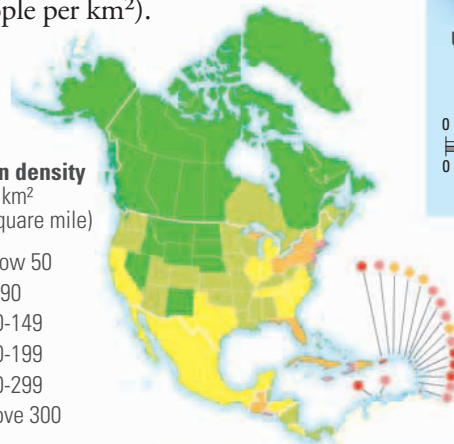
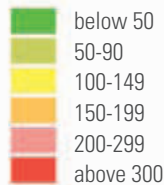
- **Covers** 16.5 percent of Earth's land area
- **Number of countries** 23
- **Biggest country** Canada
- **Smallest country** St. Kitts and Nevis
- **Languages** English, Spanish, French
- **Population of continent** Estimated at 529 million
- **Largest North American city** Mexico City, Mexico
- **Highest point** Mount McKinley (Denali) in Alaska, at 20,320 ft (6,194 m)
- **Longest river** the Mississippi-Missouri in the US, at 3,740 miles (6,019 km)
- **Biggest lake** Lake Superior, situated between the US and Canada, is the world's largest freshwater lake, with a surface area of 31,820 sq miles (82,400 sq km<sup>2</sup>)

## How many people?

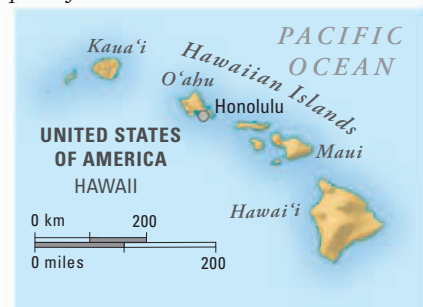
About 529 million people live in North America, more than half of them in the United States. Barbados is the most densely populated country, with 1,658 people per square mile (640 people per km<sup>2</sup>).

## Population density

People per km<sup>2</sup>  
(0.39 per square mile)



▼ **HAWAII** *The Hawaiian Islands lie in the central Pacific Ocean but are part of the United States.*



▼ **INUIT PEOPLE** *have lived in the Arctic for centuries, surviving by hunting fish, seals, walruses, and whales. Today, most Inuit live in towns or small settlements.*



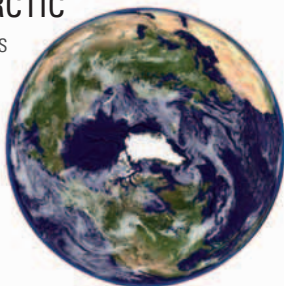
## THE POLAR REGION

The climate in the Arctic is harsh—average winter temperatures can be as low as  $-40^{\circ}\text{F}$  ( $-40^{\circ}\text{C}$ ), and in midwinter the Sun never rises.

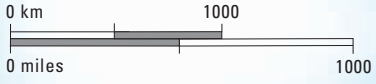
Parts of the region are permanently covered by ice. Despite this, the Arctic is home to many animals, including polar bears and seals.

## EXTENT OF THE ARCTIC

The Arctic region includes Greenland, northern Canada and Alaska, as well as the northernmost parts of Europe and Asia, and a huge area of frozen ocean around the North Pole.







The Bering Strait separates North America from Asia and is just 53 miles wide (85 km).

### FAMOUS PLACES

- The Rockies are the highest and longest mountain range in North America, stretching for 3,000 miles (4,800 km) through Canada and the United States.
- Death Valley, on the border of Nevada and California, is the continent's hottest, lowest place.
- The San Andreas Fault in California marks the place where two of the plates that make up the Earth's crust meet. Movement here causes frequent earthquakes.



Measured by the length of its shoreline, Hudson Bay in northern Canada is the world's largest bay.

### The Caribbean

There are more than 7,000 islands, islets, and reefs in the Caribbean Sea. Most are too small to be inhabited, but the bigger ones make up 13 countries and a number of dependent territories. In the summer months, the Caribbean is often hit by huge tropical storms, called hurricanes, that can do great damage.

◀ THE ARCTIC OCEAN contains large areas of floating sea ice. This forms when the temperature drops to about 28.8°F (-1.8°C) and causes the seawater to freeze.

The Panama Canal allows boats to travel between the Atlantic and Pacific Oceans, without going around South America.



# Life in North America

The first people crossed from Asia to modern-day Alaska thousands of years ago. Today's North Americans include the descendants of Native peoples, European settlers, and African slaves.

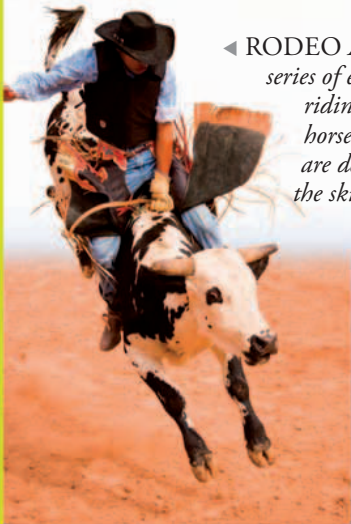
## Cattle ranching

The cowboys made famous in movies were ranch hands employed to round up and drive the large herds of cattle in the American West. Cattle are still raised for their meat in the United States and Canada.



▲ RANCH Cattle are now raised on large ranches, like this one in Alberta, Canada.

◀ RODEO A rodeo is a series of events, such as riding a bucking horse or bull, that are designed to test the skill of a cowboy.



## INDUSTRY

North American companies have been responsible for the invention of the silicon chip, the microprocessor, the iPod, and many other advances in computer technology.

## LANDSCAPE

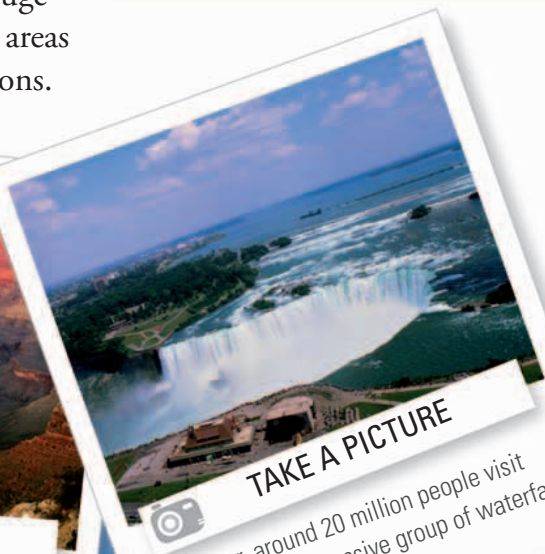
North America contains a huge variety of landscapes. Many areas are popular tourist destinations.



TAKE A PICTURE  
The Grand Canyon is a steep-sided gorge in the US state of Arizona. It has been cut out of the rock by the Colorado River.

## FAMOUS NORTH AMERICANS

- **Barack Obama** (born 1961) The first African-American president of the United States, elected in 2008 after promising to bring change to the country.
- **Amelia Earhart** (1897–1937) American pioneer of flying, and the first woman to fly solo across the Atlantic (in 1928).
- **Frida Kahlo** (1907–54) Mexican artist who is famous for her self-portraits, painted in vibrant colors.
- **Sir Frederick Banting** (1891–1941) and **Charles Best** (1899–1978) Canadian scientists who discovered insulin, a drug now used to treat millions of people who suffer from diabetes.



TAKE A PICTURE  
Each year, around 20 million people visit Niagara Falls, a massive group of waterfalls on the US-Canadian border.

▼ MANHATTAN  
New York City is the biggest city in the US.





## MUSIC

The United States is the birthplace of some of the world's most popular styles of music, including jazz, rock and roll, blues, hip-hop, and country music. Jazz, blues, and rock all evolved from the blending of African and European musical styles that started in communities in the South.

### Basketball

is a sport using a ball and hoops and two teams of five players. The game was first played in the 1890s.

## SPORTS

The most popular spectator sports in the United States are basketball, baseball,

football, and ice hockey. Fans often show intense dedication to their local teams, even wearing costumes and face paint. In Mexico and Central America, soccer is the most important sport.



*Football is a contact sport in which tackling is essential, so players wear helmets and pads to protect themselves from injury.*

## CAR CULTURE

**People in the United States and Canada** own a lot of cars—19 million new ones were sold in 2007, and in the US there is more than one car on the road for every licensed driver. Many of these vehicles are built in Detroit, Michigan, although the US car industry has lost ground to foreign competitors in recent years.



*American towns are designed around the car, with streets laid out in a grid pattern.*

## NATIVE AMERICANS

Native Americans are the descendants of the original inhabitants of North America. There are about two million Native people living in the US today and one million in Canada.



*When Europeans first arrived in North America in the 1500s, they thought they were in Asia and called the Native people Indians. The term "American Indian" was born.*

## DID YOU KNOW? FASCINATING FACTS

**1** Canada's 151,000-mile (243,000-km) coastline is the longest of any country in the world.



**2** Alaska used to belong to Russia. The United States bought it from the Russians in 1867 for a bargain price of just two cents per acre (.0040 km<sup>2</sup>).



**3** America is named after the Italian Amerigo Vespucci, who was one of the first European explorers to travel to the New World.



**4** The five Great Lakes on the US-Canadian border are the largest group of freshwater lakes in the world. They cover an area about the same size as the United Kingdom.



**5** Chocolate first appeared in Mexico and Central America at least 1,600 years ago, as a bitter-tasting drink called xocolatl.

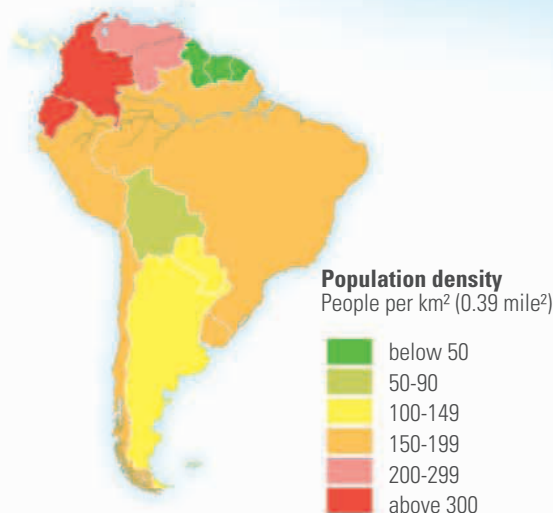






# South America

South America is the fourth-largest continent. It contains the world's longest mountain range, biggest rain forest, driest desert, and highest waterfall. It is also home to a vast range of plants and animals, and to 382 million people.



## SOUTH AMERICAN FACTS

- **Covers** approximately 12 percent of Earth's land area
- **Number of countries** 12
- **Biggest country** Brazil
- **Smallest independent country** Surinam
- **Languages** Spanish, Portuguese, French, Dutch, and many native Indian languages
- **Population of continent** Estimated at 382 million
- **Largest South American city** Sao Paulo, Brazil
- **Highest point** Cerro Aconcagua in Argentina, at 22,833 ft (6,959 m)
- **Longest river** the Amazon is approximately 4,000 miles (6,437 km) long
- **Biggest lake** Lake Titicaca, situated between Peru and Bolivia

## THE AMAZON

The Amazon is the world's second-longest river and the largest by volume. It pours so much water into the Atlantic that drinkable water can be drawn out of the ocean three-quarters of a mile (1 km) from the river's mouth.



▲ **FOREST** *The Amazon is surrounded by the biggest tropical rain forest on Earth, home to a huge variety of wildlife and groups of native peoples.*

## How many people?

About six percent of the total world population live in South America. Brazil is the largest country and has the biggest population, while Colombia and Ecuador are the most densely populated countries.



▲ **CATTLE RANCHING** *Vast areas of forest are being cut down each year to clear land for cattle ranches, threatening the area's delicate ecosystem.*

## THREATENED ZONES

The total area lost to forest clearance in the Amazon is at least 227,000 miles<sup>2</sup> (587,000 km<sup>2</sup>)—that's bigger than France.



► **HABITAT** *The weather in the rain forest is hot and humid all year round.*

## ANIMALS IN THE AMAZON

One in ten of the world's known species of plant and animal live in the Amazon rain forest, including:

- 40,000 species of plant
- 3,000 species of fish
- 1,294 species of bird
- 427 species of mammal
- 428 species of amphibian
- 378 species of reptile

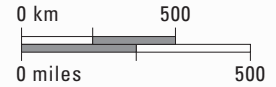






The area around Lake Maracaibo in Venezuela contains large deposits of oil.

The Orinoco is one of the largest rivers in South America (though no river there comes close to the length of the Amazon!). It is 1,330 miles (2,140 km) long.



The highlands of Colombia are one of the wettest places in the world, with one town, Tutunendo, averaging 448 in (11,394 mm) of rain each year.

**The Atacama Desert**

This desert stretches along the western coast of Chile and is the driest place on Earth. In some parts of the Atacama, no rainfall has ever been recorded.

The Pampas is a huge grassy plain that stretches across northern Argentina and Uruguay.

**FAMOUS PLACES**

- Cape Horn is the southernmost tip of South America. The seas around the cape are extremely dangerous because of high winds, huge waves, and strong currents.
- At about 4,400 miles (7,000 km) long, the Andes are the world's longest mountain range. They extend through seven countries.
- Lake Titicaca (between Bolivia and Peru) lies 12,500 ft (3,812 m) above sea level, making it the world's highest navigable lake.



▲ MACHU PICCHU The Inca people built this city in the Andes over 500 years ago. It is known as the "Lost City of the Incas" because it was forgotten for centuries, until Hiram Bingham rediscovered it in 1911.



# Life in South America

Dramatic landscapes, including the Andes mountains, lively cities, music, dancing, exuberant carnivals, and passionate soccer crowds are just some of the things to see in South America.

► **MANED WOLF**  
*This long-legged wolf lives in Uruguay.*



## WILDLIFE

This continent is home to a huge variety of animals: tropical parrots and snakes in the rain forest, bears and condors in the Andes, and anteaters and caviés on the Pampas grasslands.

## LANDSCAPE

South America contains almost every kind of landscape, including rain forest, grassland, desert, and mountain.



### TAKE A PICTURE

At 3,212 ft (979 m), Angel Falls in Venezuela is the world's highest waterfall. It was named after an American pilot, Jimmy Angel, in 1933.

## FAMOUS SOUTH AMERICANS

- **Eva Peron** (1919–1952), often known as Evita, was married to the Argentinian president, Juan Perón. She helped many poor people and campaigned for better conditions for workers.
- **Pele** (born 1940) Brazilian former soccer player, considered by many to be the greatest soccer player of all time.
- **Gabriel Garcia Marquez** (born 1927) Colombian novelist who was awarded the Nobel Prize for literature in 1982.
- **Simón Bolívar** (1783-1830), born in Venezuela, was a key leader in the successful struggle for independence of much of South America, including Peru, Venezuela, Colombia, Ecuador, and Bolivia.



▲ **LLAMA** *People who live in the Andes keep llamas for their wool and use them to carry heavy loads.*



▲ **FAVELA** *Rio is not all beaches and skyscrapers. Many of its inhabitants live in poverty in shantytowns called favelas.*

◀ **RIO DE JANEIRO** *Famous for its dramatic setting on the Atlantic coast, Brazil's second-largest city is overlooked by a giant statue of Christ the Redeemer.*





**FOOD**

Meat forms an important part of the South American diet. One traditional dish in Paraguay, Uruguay, and Argentina is a barbecue of sausages, steaks, and chicken, called *asado*. A tea called “mate” is popular in Southern Brazil and is drunk from a gourd through a silver straw.

**TOURISM**

Many people visit Rio to see the carnival or to relax on the famous beaches.

Other popular tourist attractions include Iguacu Falls and the ancient Inca city of Machu Picchu in Peru.

**PANAMA HAT**

Despite the name, these brimmed straw hats do not actually come from Panama—they are made in Ecuador.

**SOCCER**

Soccer is a passion for people in many South American countries—from children playing soccer in the streets up to fanatical support for the big teams. Brazilian soccer is famous for its fast-flowing and attacking style of play. The national team has won the World Cup a record five times.

**FARMING**

Almost a third of all the world's coffee is grown in Brazil. Other important South American crops include bananas, cocoa, and sugarcane. Chile and Argentina are important wine producers.

**MUSIC**

The **samba**, **tango**, and **bossa nova** are just some of the famous dances that come from South America. This couple is dancing the tango, a dramatic dance that originated in the slums of Buenos Aires in Argentina. Tango music is played on a type of accordion called a bandoneon, accompanied by a piano and violin.

**INDUSTRY**

Venezuela has some of the world's largest oil and gas reserves and the petroleum industry accounts for 80 percent of its exports. In Brazil, many cars run on ethanol, which is a fuel made from sugar cane.

**DID YOU KNOW? FASCINATING FACTS**

**1** Chile is the longest and thinnest country in the world. It is 2,610 miles (4,200 km) long but only 112 miles (180 km) at its widest point.



**2** The city of Ushuaia is the southernmost city in the world. It is situated on the island of Tierra del Fuego at the southern tip of Argentina.

**3** There are nearly 137 million Roman Catholics in Brazil—more than in any other country in the world.



**4** La Paz in Bolivia is the world's highest capital city at 11,942 ft (3,640 m) above sea level.

**5** Argentina was named by the first Spanish settlers, who went there in search of silver and gold. The name comes from the Latin word for silver, *argentum*.







# Africa

Africa is often called the “birthplace of humankind.” That’s because human beings originated from Africa several million years ago, although humans as we would recognize them only emerged about 200,000 years ago. Today, about 1 in 8 of the world’s population live in Africa.

## AFRICAN FACTS

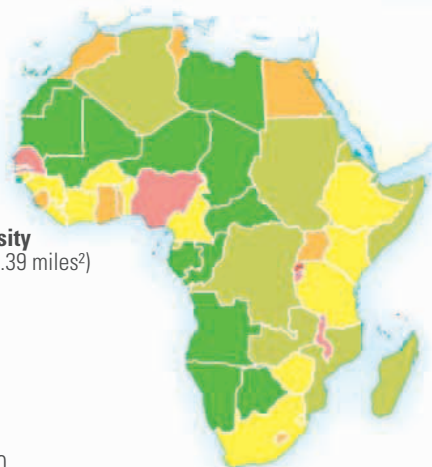
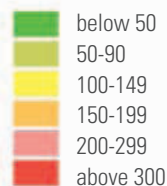
- **Covers** approximately 20 percent of Earth’s land area
- **Number of countries** 53 +dependencies
- **Biggest country** Republic of Sudan
- **Smallest country** The Seychelles
- **Languages** 1,000s
- **Population of continent** Estimated at 778 million
- **Largest African city** Egypt’s capital, Cairo
- **Highest point** Kilimanjaro in Tanzania at 19,341 ft (5,895 m)
- **Longest river** Nile, running through Uganda, Sudan, and Egypt into the Mediterranean Sea, at 4,145 miles (6,671 km)
- **Biggest lake** Lake Victoria, bordering Tanzania, Uganda, Kenya. The lake contains more than 3,000 islands, many inhabited.

## How many people?

The population of Africa is thought to be around 14 percent of the total world population. Nigeria is the most populated African country.

## Population density

People per km<sup>2</sup> (0.39 miles<sup>2</sup>)



## THE SAHARA

“Sahara” comes from the Arabic word for “desert.” The Sahara stretches across North Africa and covers parts of 11 countries. Much of it consists of vast seas of sand, with dunes up to 600 ft (180 m) high.



◀ **OASIS** *There are about 90 big oases scattered across the Sahara. These are places where underground water comes to the surface, allowing plants to grow.*

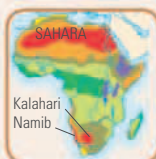


▲ **DESERT MAMMAL** *This fennec fox keeps cool by losing heat through its huge ears.*

## A VARIED LANDSCAPE

Africa’s varied landscapes include three deserts—the Sahara (Earth’s largest desert) in North Africa, and the Kalahari and Namib in the south. There are also large areas of forest and grassland.

\*Red areas indicate the extent of the named deserts.







The Red Sea divides Africa from Asia. At the northernmost end, the Suez Canal allows ships to travel between the Red Sea and the Mediterranean.

The easternmost part of the continent is known as the "Horn of Africa," because it is shaped like an animal's horn.

**The Great Rift Valley**  
This huge valley cuts right through eastern Africa, from Ethiopia to Mozambique. It contains a chain of vast lakes, including Lakes Tanganyika, Victoria and Nyasa—some of the deepest lakes in the world.

**FAMOUS PLACES**

- Hottest place: the highest temperature ever recorded was 136°F (57.8°C) at Al 'Aziziyah in Libya in 1922.
- The Ngorongoro Crater in Kenya is a circular valley, enclosed by mountain walls. It is the remains of an ancient volcano. The crater is home to a huge variety of animals.
- The Okavango River does not flow into the sea. Instead, it ends in a large inland swamp, known as the Okavango Delta, in Botswana.

Madagascar is the world's fourth-largest island. It is home to many unique animals, such as lemurs and fossas, which are not found anywhere else in the world.



# Life in Africa

Home to the world's longest river and its biggest desert, to one of the oldest tourist attractions, and to some of the most dramatic wildlife on the planet, Africa is a fascinating continent.

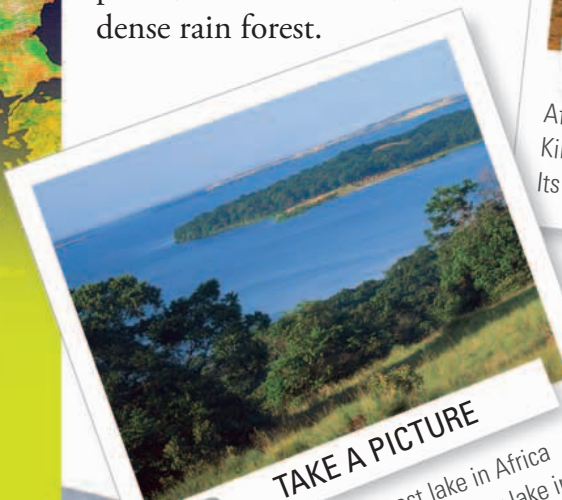
## LANDSCAPE

Africa contains a huge variety of landscapes, from snow-capped mountains to baking deserts. Northern Africa is mostly desert, while farther south are grassy plains, called savannas, and dense rain forest.



### TAKE A PICTURE

Africa's highest mountain is Mount Kilimanjaro in Tanzania, at 19,340 ft (5,895 m). Its peak is always covered in snow.



### TAKE A PICTURE

Lake Victoria is the largest lake in Africa and the second largest freshwater lake in the world.

▼ **NAIROBI** Only around one out of every five Africans lives in a big city like Nairobi, the capital of Kenya.



## FAMOUS AFRICANS

- **Nelson Mandela** (born 1918) Former political prisoner who became South Africa's first fully democratically elected president in 1994.
- **Kofi Annan** (born 1938) Secretary General of the United Nations (1997–2007). Winner of the Nobel Peace Prize in 2001.
- **Desmond Tutu** (born 1931) Former archbishop of Cape Town in South Africa, and an anti-apartheid campaigner.
- **Haile Gebreselassie** (born 1973) Ethiopian long-distance runner who has broken numerous world records.

## Traditional African villages

Most Africans live in the countryside, often in small villages. Many homes, like these in a Shona village, are made from mud. People live very simply, with no access to electricity.



► **MANY** Africans make their living from farming or herding. This Samburu man in Kenya is herding his goats.





## FARMING

About 60 percent of African workers are subsistence farmers, farming their own land and growing crops such as barley, cassava, corn, sorghum, and sweet potatoes to feed their families. Many also produce “cash crops,” such as coffee, which are sold to make money. Larger farms usually grow cotton, cocoa, or rubber as cash crops.



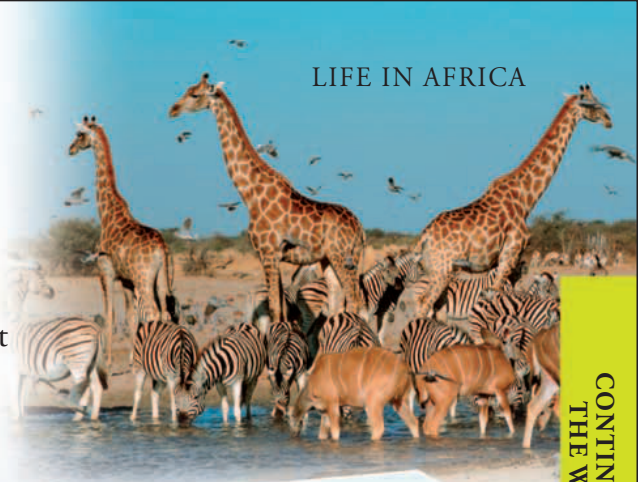
*Some places in Africa use wind pumps to pump water from the ground, because many areas are not connected to a national electricity supply.*

## FOOD

The main ingredients of most African dishes are the staple crops grown on local farms—corn, cassava, yams, rice, beans—along with various green vegetables. One popular dish eaten across West Africa is Jollof rice. It is made from rice with tomatoes, onions, spices, and chili, all cooked in one pot, and is often served with cooked meat or fish.

## WILDLIFE

Africa is famous for its zebras, giraffes, lions, and other large animals. But it is also home to many other creatures, from the 500 different species of fish that live in Lake Malawi to colonies of penguins in South Africa.



## TOURISM



## INDUSTRY

The main African industries are mining for gold, diamonds, and copper, as well as oil production. The biggest oil producers are Nigeria and Libya.

## TOURISM

Each year, about 3 million people visit the ancient pyramids at Giza in Egypt, making them Africa’s number one tourist attraction. Many people also travel to Africa to see the continent’s spectacular wildlife.

**Diamonds** About half of all diamonds come from southern Africa, especially South Africa and Botswana. The largest diamond ever found, the Cullinan, was mined in South Africa in 1905.

## MUSIC

Most African music features complex rhythms, created through patterns of drumbeats. African musicians also play flutes, xylophones, and stringed instruments.

► **MBIRA** *This African instrument is made of metal keys set on a wooden soundboard. The musician plucks the keys with his fingers.*



## DID YOU KNOW? FASCINATING FACTS

**1** One of the toughest races on Earth is the *Marathon des Sables* (Marathon of the Sands), which takes place each year in Morocco. Entrants run 156 miles (254 km) across the desert in six days.



**2** Malaria is a huge killer in Africa. Many people die as a result of mosquito bites, which pass on this disease.

**3** Many African children don’t get the chance to go to school. In Mali in West Africa, for example, only one out of every three children goes to elementary school.



**4** At 4,184 miles (6,695 km), the Nile is the world’s longest river. It flows north through 10 African countries.

**5** The world’s five fastest land animals are the cheetah, pronghorn antelope, wildebeest, lion, and Thomson’s gazelle. Four are found in Africa. The pronghorn is native to North America.





# Europe

Unlike many of the other continents, Europe is not a separate landmass—it is joined to Asia. Europe's eastern boundary is formed by the Ural Mountains and the Caspian Sea. Russia falls into both Europe and Asia.

## EUROPEAN FACTS

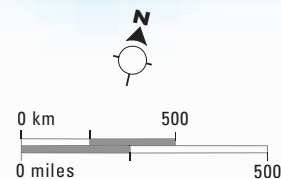
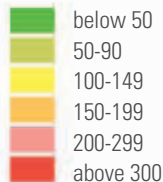
- **Covers** approximately 7 percent of Earth's land area
- **Number of countries** More than 50
- **Biggest country** Russia (note that part of Russia also lies in Asia)
- **Smallest country** Vatican City
- **Languages** More than 50
- **Population of continent** Estimated at 731 million
- **Largest European city** Moscow
- **Highest point** Mount Elbrus in Russia at 18,510 ft (5,642 m) high
- **Longest river** the Volga in Russia is 2,292 miles (3,688 km) long
- **Biggest lake** Lake Ladoga in Russia

## How many people?

The 731 million Europeans make up about 11 percent of the total world population. Russia has the largest population, while the most densely populated country is the Netherlands.

## Population density

People per km<sup>2</sup> (0.39 miles<sup>2</sup>)



▲ **ST. BASIL'S CATHEDRAL**  
*This beautiful cathedral, with its onion-shaped domes, stands in Red Square in Moscow, Russia.*

## THE ALPS

Extending through seven countries, the Alps are the largest mountain system in Europe. They are a popular vacation destination in both summer and winter for skiing, mountaineering, and walking.

▼ **ALPS Mont Blanc** is the highest peak in the Alps at 15,774 ft (4,808 m).



## RESCUE DOG

Specially trained German shepherd dogs are used in the Alps to find missing people. They can smell a person buried under snow.





**FAMOUS PLACES**

■ Surtsey, a small island off Iceland, was formed by the eruption of an underwater volcano. It rose above sea level in 1963–68, making it one of the world's youngest islands.

■ The Low Countries—Belgium and the Netherlands—are so low that some of the land actually lies below sea level and has to be protected by huge dikes.

*The island of Iceland is extremely volcanically active. It is home to several volcanoes and many geysers.*

*The northeastern part of Europe, known as Scandinavia, includes the countries of Norway, Sweden, Denmark, and Finland.*



**The Mediterranean Sea**  
Europe is divided from Africa by the Mediterranean, a sea that is almost completely surrounded by land. The only way in and out to the Atlantic Ocean is through the Strait of Gibraltar, which is just 9 miles (14 km) wide.

*Mount Etna, on the island of Sicily, is the largest active volcano in Europe. Etna erupts almost continuously, making it one of the world's most active volcanoes.*

*Istanbul, the largest city in Turkey, is the only city to span two continents. Part is in Europe, and part in Asia.*



# Life in Europe

Europe is only slightly bigger than the United States, but has more than twice the US population. It is also crowded with countries—around 50 are crammed into the tiny continent.

## EUROPEAN UNION

The European Union (EU) is a political and economic union of 27 countries that operate as a single market. This means that people, goods, and money can move freely between the various countries. Sixteen of the member states share a common currency, the euro. The EU has its own parliament, court of justice, and central bank.



*The circle of stars on the EU flag represent unity among the members.*



### TAKE A PICTURE

Chambord is one of more than 300 beautiful châteaux (castles) in the Loire Valley in France.



### TAKE A PICTURE

Stonehenge is a circle of standing stones, built in prehistoric times, that stands on Salisbury Plain in Britain.

▼ *ROME'S mix of old and new buildings shows how the city has evolved over centuries.*



## FAMOUS EUROPEANS

- **Mother Teresa** (1910–1997) Albanian Roman Catholic nun who was famous for her humanitarian work.
- **Albert Einstein** (1879–1955) Nobel-Prize-winning German physicist, and one of the most famous scientists of all time.
- **Pablo Picasso** (1881–1973) Spanish painter and sculptor, who was the most influential artist of the 20th century.
- **Louis Braille** (1809–1852) French inventor of Braille, a system used by blind people to read.
- **Marie Curie** (1867–1934) Polish scientist who researched radioactivity and won two Nobel Prizes for her work.



## FOOD

Pasta, pizza, croissants, moussaka, goulash, and profiteroles are just some of the foods that originated in Europe and are now popular worldwide.



Cheese from France



Sausages from Germany



Tapas from Spain



Pasta from Italy

## SPORTS

Soccer, tennis, cricket, golf, and rugby are played around the world, but were all invented in Europe. Rugby, for example, was a variant of soccer invented at a school in the UK in the early 19th century.



## WEALTH

All the European countries have high standards of living, and even poorer Europeans are well off compared to people in the developing world. According to World Bank statistics, the three richest countries in the world are Luxembourg, Norway, and Switzerland—all in Europe.



## MUSIC

Europe is the birthplace of classical music, opera, and the modern orchestra. These styles of music were performed in concert halls or opera houses, many of them extremely grand buildings, with audiences paying to attend. Europe's famous composers include Mozart, Haydn, Bach, Beethoven, Verdi, and Puccini.



▲ MOZART (1756-1791)

## CROWDED CONTINENT

Europe is densely populated. Overall, there are about 181 people per square mile (70 per square kilometer), compared to just 59 people per square mile (23 per square kilometer) in North America. About three-quarters of its population live in towns and cities.



London, UK

## TOURISM

France is the most visited country in the world, with almost 82 million visitors in 2007. Tourists travel to Europe to see the many historic buildings and cities, and to relax on the Mediterranean beaches.



Eiffel Tower, Paris, France

## DID YOU KNOW? FASCINATING FACTS

**1** The Danube River flows through 10 European countries and four European capital cities (Vienna, Bratislava, Budapest, and Belgrade).

**2** Europe's population is shrinking. The average number of births per woman is just 1.52. Experts estimate that by 2050 Europeans will make up just 7 percent of the world's population (currently 11 percent).



**3** Europe is named after Europa, a character in Greek mythology. She was a princess who was abducted by the god Zeus, who had disguised himself as a white bull.



**4** Swiss people eat more chocolate than any other nation. Each of them munches through an average of 2½ lb (11.6 kg) of chocolate in a year.

**5** The three smallest states in Europe are: Monaco (30,000 residents), San Marino (25,000 residents), and Vatican City (900 residents). Vatican City is just 0.17 miles<sup>2</sup> (0.44 km<sup>2</sup>).







# Asia

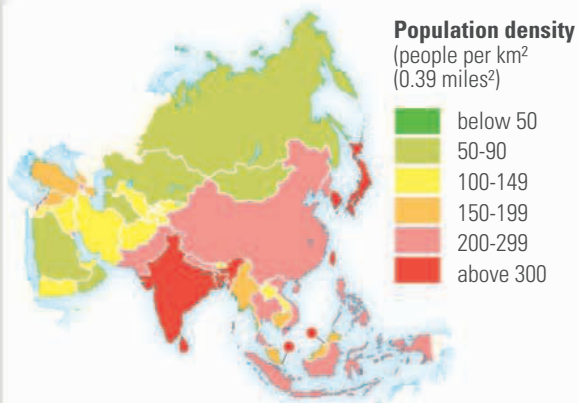
Asia is the biggest continent, covering about a third of Earth's land area. It has the biggest population, and it contains the world's biggest country, highest mountain, and largest lake.

## ASIAN FACTS

- **Covers** 30 percent of Earth's land area
- **Number of countries** around 48
- **Biggest country** Russia (although part of Russia also lies in Europe)
- **Smallest country** the Maldives
- **Languages** Unknown, but more than 200
- **Population of continent** Over 4 billion (over 60 percent of the world's population)
- **Largest Asian city** Tokyo, Japan
- **Highest point** Mount Everest, on the border of Nepal and China, at 29,028 ft (8,848 m)
- **Longest river** the Yangtze River (Chang Jiang) in China is 3,915 miles (6,300 km) long
- **Biggest lake** the Caspian Sea is the world's largest lake

## How many people?

More than 4 billion people live in Asia—that's about two out of every three people in the world. China has the biggest population, with 1.3 billion people.



## FAMOUS PLACES

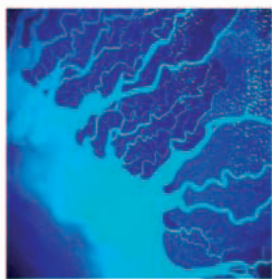
- Mount Pinatubo is an active volcano in the Philippines. It exploded in 1991 in one of the biggest eruptions ever recorded.
- The Dead Sea is actually an extremely salty lake on the border of Israel and Jordan. It is the lowest place on Earth, at 1,312 ft (400 m) below sea level.
- K2 is the second-highest mountain on Earth, after Mount Everest. It is located in Pakistan.



## THE GANGES

The Ganges is the longest river in the Indian Subcontinent and a sacred river for Hindus. Each year, thousands of pilgrims visit Varanasi and other holy cities along its banks.

▼ **BATHING**  
*in the Ganges is said to wash away sins.*



## THE DELTA

This satellite picture shows the Ganges delta in Bangladesh. This area is very low lying and often floods.







CONTINENTS OF THE WORLD

The Ural Mountains in Russia form the boundary between Asia and Europe.

The northern and central part of Russia is known as Siberia. This region is bitterly cold in the winter.



▲ DUBAI is the biggest city in the United Arab Emirates (UAE). Most of it has been built in the last 40 years.

A belt of thousands of islands stretches from southeast Asia to Australia. There are more than 13,500 islands in Indonesia alone.



# Life in Asia

Asia contains just about everything—great wealth and extreme poverty, modern ways and ancient traditions, empty deserts and overcrowded cities, small-scale farming and high-tech industry.

## FAMOUS ASIANS

- **Benazir Bhutto** (1953–2007) Pakistani politician. Bhutto was elected prime minister twice, becoming the first woman elected to lead a Muslim state, but she was assassinated in 2007.
- **Yuri Gagarin** (1934–68) Russian astronaut. He was the first person to travel into space and to orbit the Earth.
- **Tenzing Norgay** (1914–86) Nepalese mountaineer who in 1953 became one of the first two men to reach the summit of Mount Everest.
- **Mahatma Gandhi** (1869–1948) Indian political and spiritual leader. He helped free India from British control.



## TOURISM

Asia's most-visited tourist attractions are the Great Wall of China and the Taj Mahal in India. There are more modern attractions in Dubai, famous for its shopping and nightlife, and home to the world's tallest hotel.



### TAKE A PICTURE

These limestone pinnacles near Yangshou in China were formed by rainwater, which has gradually worn away all the surrounding rock.



### TAKE A PICTURE

Mount Fuji is a volcano near Tokyo in Japan. The Japanese consider it a sacred mountain and it often appears in Japanese paintings.

▼ *MUMBAI is the biggest city in India. It is the country's business center and home to the Bollywood movie industry.*







## OIL

About 80 percent of the world's easily accessible oil is in the Middle East, and money from oil has made some of the countries in this region extremely rich.

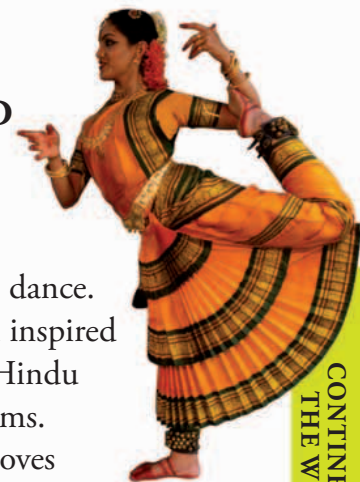


## MANUFACTURING

From clothes to cars, lots of the goods sold in Western countries are made in Asia. Many companies have factories in Asia because it is cheaper to employ workers there than in the West.

## MUSIC AND DANCE

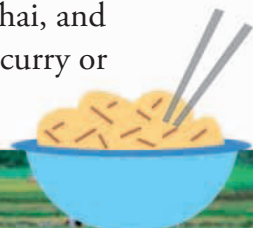
This girl is performing a classical Indian dance. These are often inspired by traditional Hindu stories and poems. The dancer's moves and hand gestures tell the story.



CONTINENTS OF THE WORLD

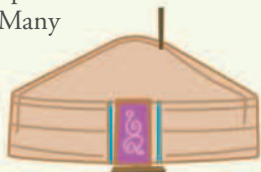
## FOOD

Rice is the staple (main) food for many people in Asia. It is served with many Chinese, Thai, and Indian dishes, such as curry or stir-fried foods.



## ANCIENT AND MODERN

There are huge differences in people's lifestyles around the continent. Many Asians live in big modern cities such as Tokyo and Beijing. But in other areas, people such as the Bedouin are living much as their ancestors did hundreds of years ago. Many Bedouin still live in tents and move from place to place.



In parts of Mongolia, nomadic farmers live in traditional felt tents, called yurts.



In Japan, many people live in apartment buildings.

## WILDLIFE

Tigers are only found in eastern and southern Asia. The tiger is now an endangered animal, because large areas of its habitat



have been destroyed and it is often hunted for its skin.

## TECHNOLOGY

Japan is a world leader in manufacturing televisions, music players, game consoles, cameras, and other electronics. India is one of the world's largest exporters of software and other computer services.

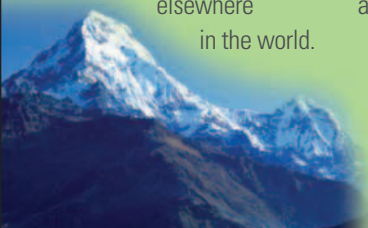


## FARMING

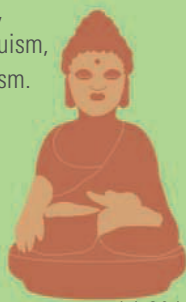
About half of all Asians make their living from farming, and rice is the continent's biggest crop. It has to be grown in wet conditions, often in a flooded paddy field.

## DID YOU KNOW? FASCINATING FACTS

**1** The Himalayas contain 14 peaks that are over 26,000 ft (8,000 m) high—there are no other mountains this high elsewhere in the world.



**2** Asia was the birthplace of all the world's major religions, including Judaism, Christianity, Islam, Hinduism, and Buddhism.



**3** The world's deepest lake is Lake Baikal in Russia, at 5,371 ft (1,637 m). It contains more water than the five North American Great Lakes.

**4** Japan is home to 10 percent of all the active volcanoes in the world. It has about 40 active volcanoes, while another 148 are dormant.



**5** The Indian railroad system is the world's largest employer, with more than 1.6 million members of staff.





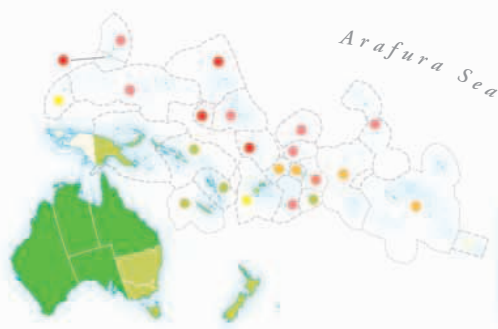


# Australasia and Oceania

The region known as Australasia includes the countries of Australia, New Zealand, and Papua New Guinea. Australia is so big that it is a continent in its own right. To the east lie thousands of tiny Pacific Islands, known as Oceania.

## FACTS ABOUT THE REGION

- **Covers** approximately 6 percent of the Earth's land area
- **Number of countries** 14 independent countries and 16 dependencies
- **Biggest country** Australia, which is also a continent
- **Languages** there are 25 official languages in the region
- **Population of the region** estimated at around 30 million
- **Largest city** 4.3 million people live in Sydney, Australia
- **Highest point** Mt. Wilhelm in Papua New Guinea is 14,793 ft (4,509 m) high
- **Longest river** the Murray-Darling in Australia is 2,330 miles (3,750 km) long
- **Biggest lake** Lake Eyre in Australia



**Population density**  
People per km<sup>2</sup> (0.39 miles<sup>2</sup>)



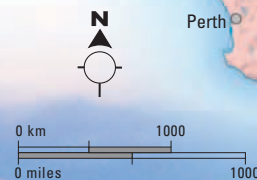
## How many people?

About 30 million people live in Australasia and Oceania. This is just 0.5 percent of the total world population. The vast majority of people live in Australia, which has a population of 21 million.

## THE OUTBACK

Away from the coasts, Australia is mostly a hot, dry, desertlike plain, known as the outback. Very few people live there, but it is home to many animals, including kangaroos, dingoes, wombats, and emus, and to huge sheep and cattle farms.

▼ **ULURU, or Ayers Rock,** is a large outcrop of sandstone rock in the center of Australia. Local Aboriginal people consider it a sacred site.





# PACIFIC OCEAN

Huahine Tahiti, Polynesia



## FAMOUS PLACES

- The Great Barrier Reef, off Australia's northeast coast, is the world's largest coral reef. (👁️ p. 76). It has built up over thousands of years.
- The town of Rotorua on New Zealand's North Island is famous for its geysers and bubbling pools of hot mud, caused by volcanic activity under the ground.

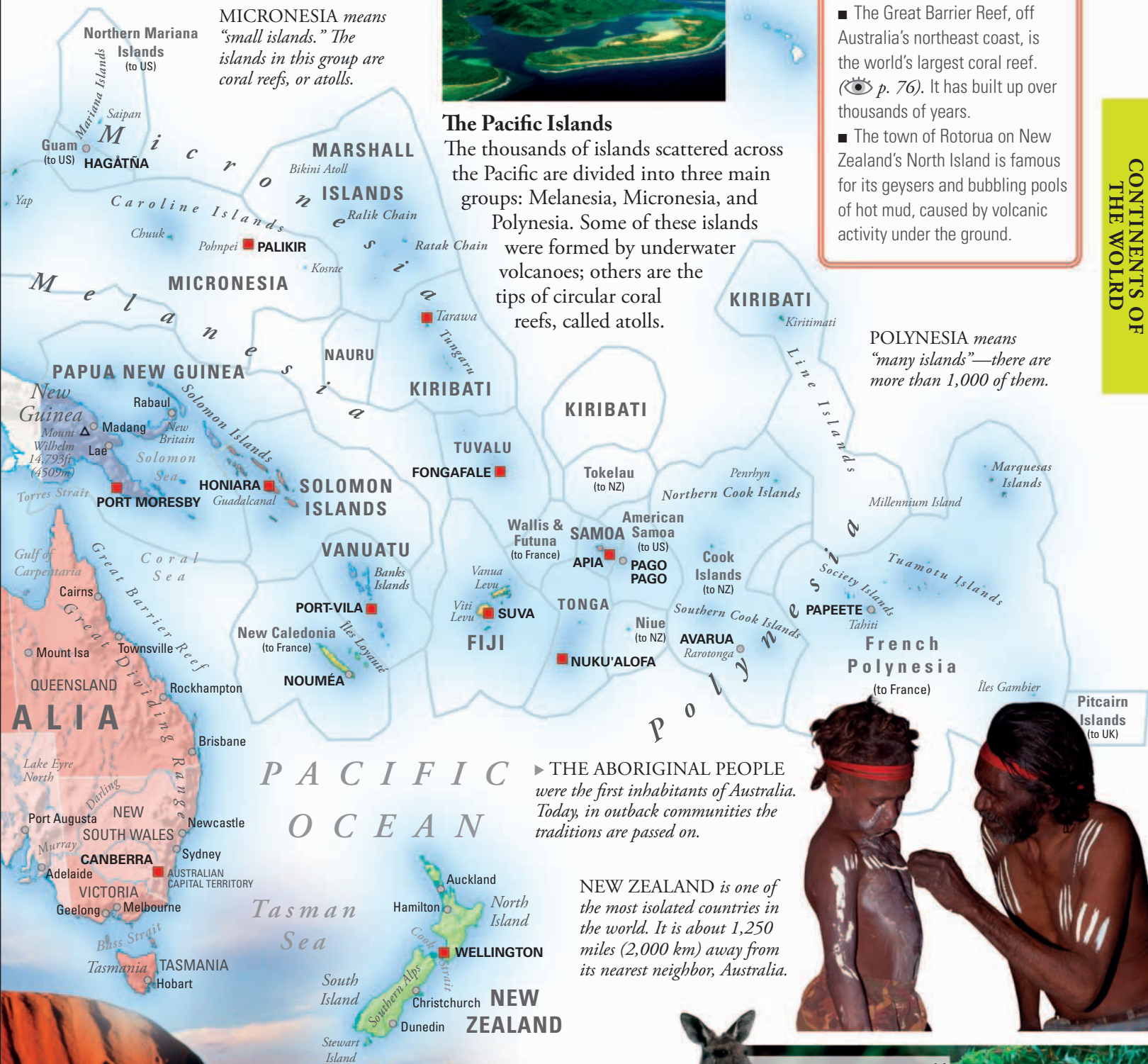
CONTINENTS OF THE WORLD

MICRONESIA means "small islands." The islands in this group are coral reefs, or atolls.

### The Pacific Islands

The thousands of islands scattered across the Pacific are divided into three main groups: Melanesia, Micronesia, and Polynesia. Some of these islands were formed by underwater volcanoes; others are the tips of circular coral reefs, called atolls.

POLYNESIA means "many islands"—there are more than 1,000 of them.



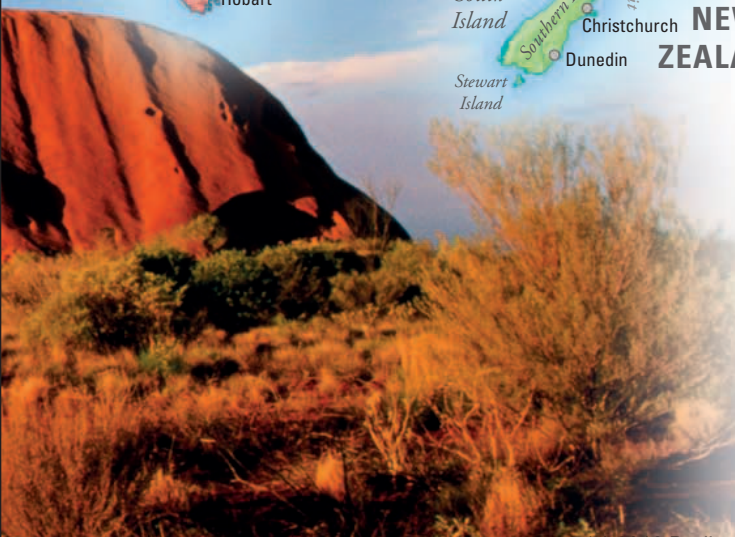
▶ THE ABORIGINAL PEOPLE were the first inhabitants of Australia. Today, in outback communities the traditions are passed on.



NEW ZEALAND is one of the most isolated countries in the world. It is about 1,250 miles (2,000 km) away from its nearest neighbor, Australia.

▶ WILDLIFE Kangaroos live in the bush, surviving on grasses. They are most active in the early morning and evening, when it is cooler.

▶ DINGOES are wild dogs. They come from domestic dogs that people brought to Australia.





# Life in Australasia and Oceania



▲ **KOALA** *These marsupials rarely drink, obtaining moisture from the leaves they eat.*

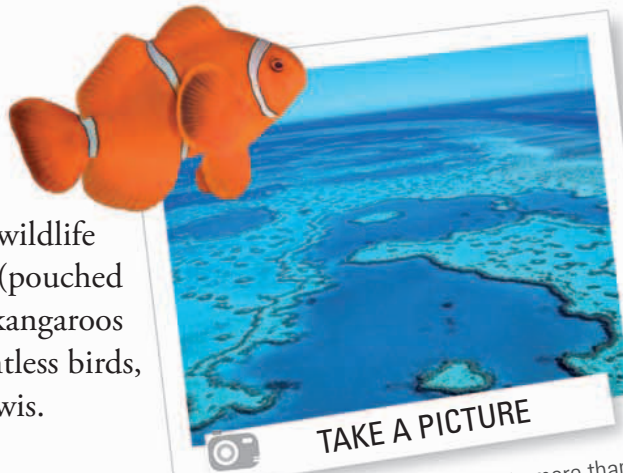
This region was one of the last parts of the world to be settled by people. The Maori, for example, arrived in New Zealand only a thousand years ago. The region is still sparsely populated, with an average of just 10 people per square mile (4 per square kilometer).

## WILDLIFE

The region's unique wildlife includes marsupials (pouched mammals), such as kangaroos and koalas, and flightless birds, such as emus and kiwis.



**Kiwi**



### TAKE A PICTURE

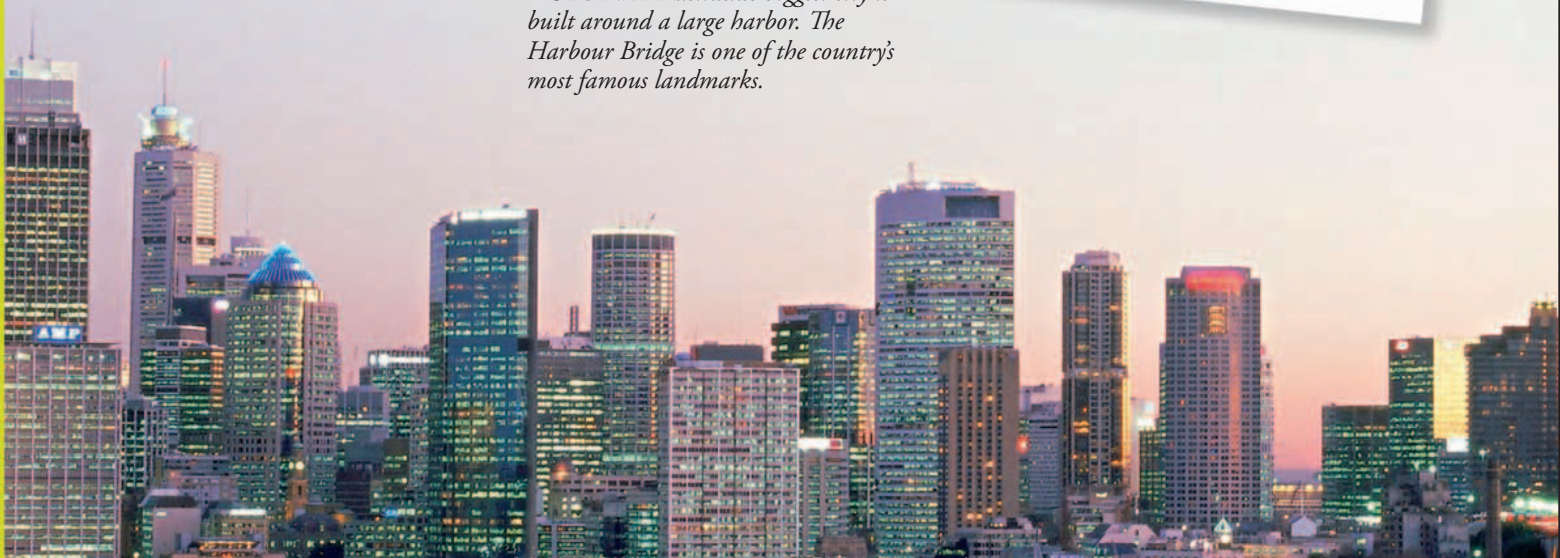
The Great Barrier Reef is home to more than 1,500 species of fish and 400 species of coral, as well as thousands of plants.



### TAKE A PICTURE

New Zealand's southwest coast is punctured by many long, narrow inlets, known as fjords. The most famous is Milford Sound.

▼ **SYDNEY** *Australia's biggest city is built around a large harbor. The Harbour Bridge is one of the country's most famous landmarks.*



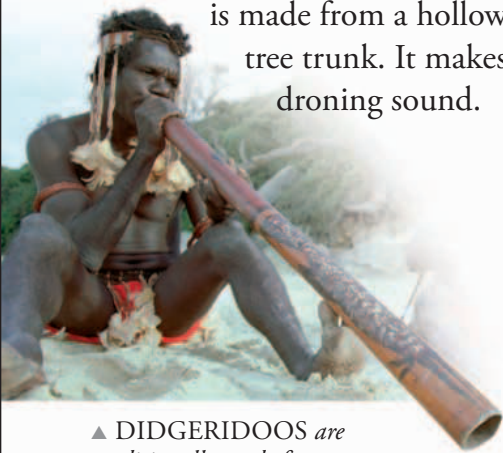
## FAMOUS AUSTRALASIANS

- **Howard Florey** (1898–1968) Australian pharmacologist who was awarded the Nobel Prize for his work in developing the drug penicillin.
- **Cathy Freeman** (born 1973) Australian sprinter. At the Sydney Olympics in 2000 she became the first Aboriginal Australian to win a gold medal in running.
- **Ernest Rutherford** (1871–1937) New Zealand scientist and Nobel Prize winner whose investigations revealed the structure of the atom.
- **Jonah Lomu** (born 1975) New Zealand rugby player. Lomu is the all-time top try scorer in the Rugby World Cup.



## MUSIC

This traditional Australian wind instrument, called a didgeridoo, is made from a hollow tree trunk. It makes a droning sound.



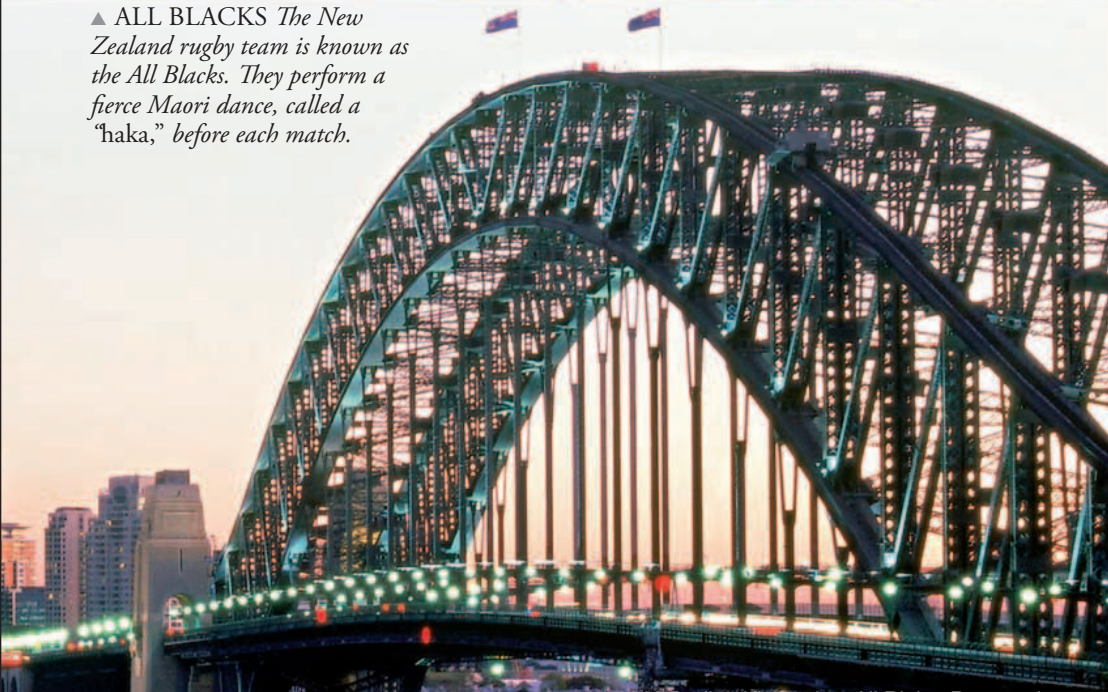
▲ DIDGERIDOOS are traditionally made from Eucalyptus trees.

## SPORTS

The most popular spectator sports in Australia and New Zealand are cricket and rugby. New Zealand is also famous for extreme sports, such as bungee jumping, white water rafting, and snowboarding.



▲ ALL BLACKS The New Zealand rugby team is known as the All Blacks. They perform a fierce Maori dance, called a "haka," before each match.



## TOURISM

Many people visit Australasia to take part in outdoor activities, such as snorkeling on the Barrier Reef, surfing and windsurfing on Australia's beaches, and trekking in New Zealand.

## FARMING

Sheep farming is important in both Australia and New Zealand—in fact, there are about five times as many sheep as people in Australia. Wool and meat are among the countries' biggest exports.



## DID YOU KNOW? FASCINATING FACTS

1 Australia is the flattest of all the continents. Its highest point, Mount Kosciuszko, is only 7,310 ft (2,228 meters) high—just a quarter of the height of Mount Everest.



2 No one knows exactly how many islands there are in the Pacific Ocean. Estimates vary from 20,000 to 30,000.



3 New Zealand is the home of bungee jumping. One of the pioneers of this extreme sport was a New Zealander named A. J. Hackett, who demonstrated it in 1987 by bungee jumping off the Eiffel Tower in Paris, France.



4 One of the world's most deadly spiders, the Sydney funnel-web, lives in Australia. Its bite could kill, but, luckily an antivenom was invented in the 1980s, so there is a cure—so long as you get to the hospital quickly.



5 About 820 different languages are spoken in Papua New Guinea.

▼ PAPUA NEW GUINEA tribesmen during a festival.





# World flags

Every country in the world has its own flag. Countries use flags to highlight their identity.

## NORTH AND SOUTH AMERICA



Antigua & Barbuda



Argentina



Bahamas



Barbados



Belize



Bolivia



Brazil



Canada



Grenada



Guatemala



Guyana



Haiti



Honduras



Jamaica



Mexico



Nicaragua



United States of America



Uruguay



Venezuela

## AFRICA



Algeria



Angola



Benin



Botswana



Burkina



Djibouti



Egypt



Equatorial Guinea



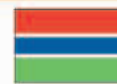
Eritrea



Ethiopia



Gabon



Gambia



Ghana



Malawi



Mali



Mauritania



Morocco



Mozambique



Namibia



Niger



Nigeria



Tanzania



Togo



Tunisia



Uganda



Zambia



Zimbabwe



Albania

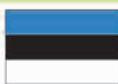


Andorra

## EUROPE



Denmark



Estonia



Finland



France



Germany



Greece



Hungary



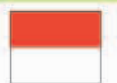
Iceland



Malta



Moldova



Monaco



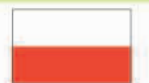
Montenegro



The Netherlands



Norway



Poland



Portugal



Romania

## RUSSIA AND CENTRAL ASIA



Vatican City



Armenia



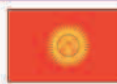
Azerbaijan



Georgia



Kazakhstan



Kyrgyzstan



Russian Federation



Tajikistan



Cambodia



China



East Timor



India



Indonesia



Iran



Iraq



Israel



Mongolia



Nepal



North Korea



Oman



Pakistan



Papua New Guinea



Philippines



Qatar



Turkey

## AUSTRALIA AND THE PACIFIC



United Arab Emirates



Vietnam



Yemen



Australia



Fiji



Kiribati



Marshall Islands



Micronesia



■ **Religion:** the flags of many European countries feature the Christian cross; the flags of many Islamic countries are based around the four traditional Arab colors—red, white, green, and black.

■ **Regions:** some countries that are made up of different regions show this in their flags. The crosses of St. George, St. Patrick, and St. Andrew in the UK flag represent England, Ireland, and Scotland, respectively.

■ **Tricolors:** many flags consist of three colored vertical stripes, known as a tricolor. These flags are inspired by the red, white, and blue French flag, adopted during the French Revolution.



Chile



Colombia



Costa Rica



Cuba



Dominica



Dominican Republic



Ecuador



El Salvador



Panama



Paraguay



Peru



St. Kitts and Nevis



St. Lucia



St. Vincent and The Grenadines



Suriname



Trinidad and Tobago



Burundi



Cameroon



Cape Verde



Central African Republic



Chad



Comoros



Congo



Democratic Republic of the Congo



Guinea



Guinea-Bissau



Ivory Coast



Kenya



Lesotho



Liberia



Libya



Madagascar



Rwanda



Sao Tome and Principe



Senegal



Sierra Leone



Somalia



South Africa



Sudan



Swaziland



Austria



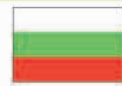
Belarus



Belgium



Bosnia & Herzegovina



Bulgaria



Croatia



Cyprus



Czech Republic



Ireland



Italy



Kosovo



Latvia



Liechtenstein



Lithuania



Luxembourg



Macedonia



San Marino



Serbia



Slovakia



Slovenia



Spain



Sweden



Switzerland



Ukraine



United Kingdom

ASIA



Turkmenistan



Uzbekistan



Afghanistan



Bahrain



Bangladesh



Bhutan



Brunei



Burma



Japan



Jordan



Kuwait



Laos



Lebanon



Malaysia



Maldives



Mauritius



Saudi Arabia



Seychelles



Singapore



South Korea



Sri Lanka



Syria



Taiwan



Thailand



Nauru



New Zealand



Palau



Samoa



Solomon Islands



Tonga



Tuvalu



Vanuatu



# CULTURE

- The world's most popular religion, Christianity, has more than 2.1 billion followers.
- The Lascaux cave paintings in France have survived more than 30,000 years.
- The most expensive painting sold to date was bought in 2006 for \$140 million.
- While 230 different languages are spoken across Europe, in Asia there are 2,197.
- Classical composer Mozart started writing music when he was just 5 years old.



Why is meditation important to Buddhists?

*Find out on pages 160–161*



What did the ancient Romans use to construct their buildings?

*Find out on pages 168–169*







*Definition:* What makes one group of people different from another? Whether it's their religious beliefs or the music they listen to, **culture** reflects the way in which people live.

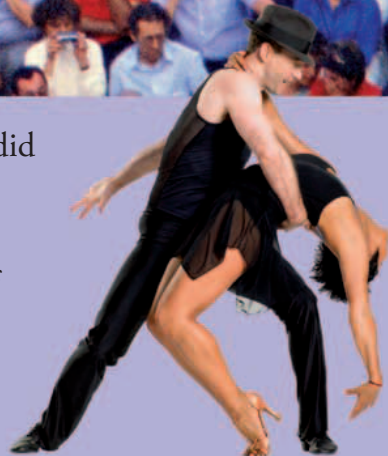


- The first Hollywood film studio was set up in an old tavern in 1911.
- The world's oldest dance form is belly dancing.
- The idea of writing and performing plays started in ancient Greece...
- ... as did the original Olympic Games, in 776 BCE.
- The Olympic motto is *Citius, Altius, Fortius*. It means "Swifter, Higher, Stronger."



When and where did salsa dancing first appear?

*Find out on pages 176–177*



How many musicians are there in an orchestra?

*Find out on pages 174–175*





# World religions

A religion is a set of beliefs that explain where the world came from, what happens after death, and how we should live our lives. Religious people come together to worship and take part in festivals. They believe in an unseen, spiritual world that cannot be explained by science.



▲ THE ABRAHAM ICON in the Church of the Holy Sepulchre, Jerusalem.

TELL ME MORE...

The vast majority of people in the world are members of a religious tradition. Roughly a third of the world's population are Christians, and a fifth are Muslims. Only 12 percent of people describe themselves as nonreligious.

**Abrahamic religions**

Judaism, Islam, and Christianity are part of the same “family” of religions, known as the Abrahamic religions. All three consider Abraham as one of the forefathers of their faith. Islam and Christianity have been spread throughout the world by immigrants and missionaries.

*The six religions with the most followers in the world are:*



**Christianity**



**Islam**

**JUDAISM**

Judaism emerged more than 3,500 years ago in the Middle East, among a tribe called the Israelites. Jews believe that there is only one God, who created the world and continues to care for it.



▼ THE YALMULKE Some Jewish men wear a skull cap—called a yarmulke—to show their respect for God.



▲ THE TORAH is the sacred text that Jews believe God dictated to Moses on Mount Sinai. It includes the Ten Commandments, which show the Jewish people the right way to live. Together with other sacred texts, it makes up the Tanakh.

► MENORAH The candles on this nine-branched holder are lit during Chanukah, the Jewish festival of light. The central candle is used to light the eight outer candles—one for each day of Chanukah.



TAKE A LOOK: PASSOVER



▲ SEDER This is a special meal in which symbolic foods are placed on a special platter in the middle of the table, including bitter herbs to signify suffering and an egg to represent rebirth.

Passover is a festival that celebrates the release of the Israelites from Egypt, where they were held in slavery. Jews believe that God sent ten plagues against the Egyptians, the last of which killed all first-born children and animals. The Israelites marked their houses with lambs' blood and God “passed over” without harming them. After this, the Pharaoh released the Israelites.





## CHRISTIANITY

Christians believe that Jesus Christ, a Jewish holy man born in Bethlehem, around 0 CE, was God in human form. According to Christian tradition he was put to death by the authorities, but returned to life three days later. The Christian Bible is made up of the Jewish Tanakh—the Old Testament—and a new set of scriptures—the New Testament.



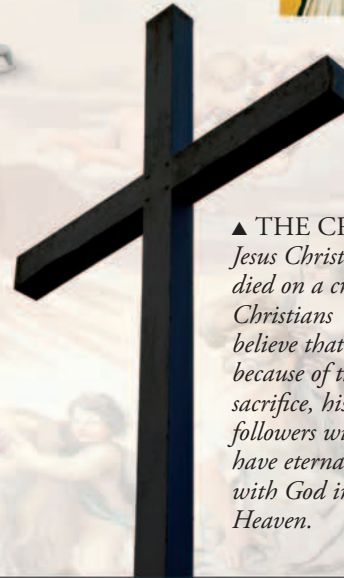
**Catholicism** There are many different branches of Christianity, the largest of which is Roman Catholicism. The leader of the Roman Catholic Church is the Pope. Catholics believe that the Pope is the successor to Saint Peter, who Jesus appointed as the first head of the Church.



◀ **THE CHALICE**  
*Holy Communion is a Christian ritual in which bread is eaten and wine is drunk to remember Jesus' sacrifice. The wine may be served in a chalice.*



▲ **THE SUPPER AT EMMAUS**  
*This stained glass window shows Jesus, having risen from the dead, sharing a meal with two disciples.*



▲ **THE CROSS**  
*Jesus Christ died on a cross. Christians believe that because of this sacrifice, his followers will have eternal life with God in Heaven.*

**Saints** are people who lived especially holy lives. Some saints are linked with specific countries or causes. For example, Saint Andrew is the patron saint of Russia and Scotland.



**Hinduism**



**Buddhism**



**Sikhism**



**Judaism**

## ISLAM

Islam was founded in Arabia in the 7th century CE by the prophet Muhammad. Muslims believe in one God, Allah, who sent 25 prophets down to Earth, the last one being Muhammad. Earlier prophets included Abraham, Moses, and Jesus.



**Ramadan** is the ninth month of the Islamic calendar, during which the *Qur'an* was revealed to Muhammad. Throughout *Ramadan* Muslims neither eat nor drink between dawn and sunset. This helps them to understand poverty and to focus their minds on prayer and reading the *Qur'an*. *Ramadan* ends with *Eid ul-Fitr*, the Fast-Breaking Festival. Believers visit the mosque and eat traditional foods with family.



**The *Qur'an*** Allah's teachings, as dictated to Muhammad, were recorded in a book called the *Qur'an*.

Muslims try to live by rules set down in the *Qur'an*.

The most important duties are known as the Five Pillars:

- praying five times a day
- giving to the needy
- fasting during *Ramadan*
- making a pilgrimage to Mecca
- proclaiming your beliefs

► **MECCA**, in Saudi Arabia, is the most holy city in Islam, and the birthplace of Muhammad. Muslims must face Mecca whenever they pray, wherever they are in the world.





Religions such as Hinduism, Buddhism, and Jainism have their roots in South and East Asia. During the 20th century, however, they spread across the world as a result of migration, and today they are practiced in both East and West. In many parts of the world, smaller, traditional religions are still practiced alongside larger, world religions.

**HINDUISM**

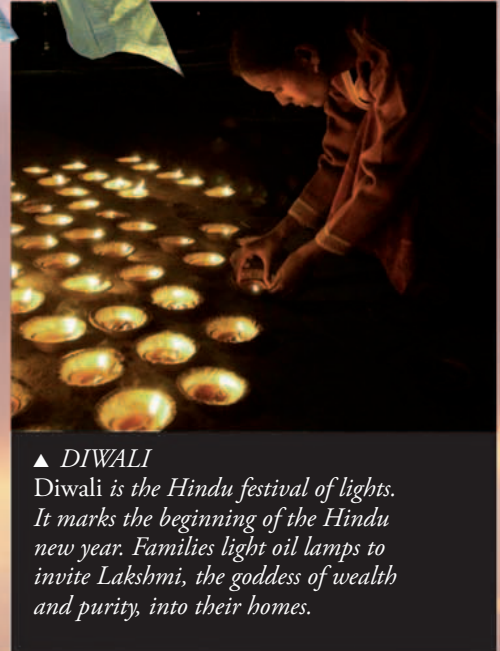
Hinduism originated in India in about 2,500 BCE. Hindus believe that souls are born again after death, and that good or bad deeds in this life result in a good or bad rebirth. The greatest goal of Hinduism is to find perfect peace and liberation by escaping the cycle of rebirth.



▲ **WORSHIP**  
Hindus believe in a multitude of gods, each with a different role. Elephant-headed Ganesh (above) is identified with wisdom. But most Hindus single out one God, such as Vishnu or Shiva, as creator and savior of the world.



▲ **THE SACRED COW** is greatly revered by Hindus. Killing cows is banned in India, and cows are allowed to wander wherever they like, even through busy traffic.



▲ **DIWALI**  
Diwali is the Hindu festival of lights. It marks the beginning of the Hindu new year. Families light oil lamps to invite Lakshmi, the goddess of wealth and purity, into their homes.

**SIKHISM**

Sikhism was founded in the 15th century by Guru Nanak, in what is now Pakistan. Sikhs believe in one all-powerful God, who is best understood through meditation. The holy book of the Sikhs is the *Guru Granth Sahib*, which is the teachings of the first leaders of the Sikh faith, the ten Gurus.

▶ **THE WORD OF GOD**  
This Indian Sikh man is working on a handwritten version of the *Guru Granth Sahib*. This holy book is treated with utmost respect: it is placed on a throne, and a sacred whisk is waved over it as it is read.



◀ **THE GOLDEN TEMPLE** in Amritsar, Punjab, India, is the most important holy place of the Sikh religion.



▶ **THE FIVE Ks**  
Followers of Sikhism outwardly show their devotion by keeping five symbolic objects starting with the letter K.

- Kesh (uncut hair). Sikhs do not cut their hair and allow their beards to grow.
- Kara (a steel bracelet)
- Kanga (a wooden comb)
- Kacch (a cotton undergarment)
- Kirpan (a steel dagger)





## BUDDHISM

Buddhism was founded in India in about 500 BCE. Buddhists do not worship a god, but, instead, follow the teachings of a man named the Buddha, who realized the true nature of reality. Like Hindus, Buddhists believe in rebirth. The Buddha showed his followers how to escape rebirth and suffering through good deeds and meditation.

### ▼ BUDDHA STATUES

*Statues of the Buddha often show him meditating in a cross-legged position. The Big Buddha on the island of Koh Samui, Thailand, was built in 1972 and is 50 ft (15 m) tall. It can be seen from several miles away.*



### ▲ PRAYER WHEELS

*Tibetan Buddhists use prayer wheels printed with mantras, which are verses that bring about spiritual understanding. As the wheel is turned, the mantra repeats itself over and over again.*



### ▲ BUDDHIST TEMPLES

*Buddhist temples are home to monks and nuns who have chosen to follow a life of good deeds and meditation. The temples are designed to symbolize the five elements: earth, air, fire, water, and wisdom, which is represented by the pinnacle at the top.*

## Traditional religions



### SHAMANISM

Shamanism is the ancient, widespread belief that an invisible world of good and evil spirits exists all around us. Specially trained people called shamans can perform rituals that allow them to communicate with the spirit world. The Chukchi people of Eastern Siberia, for example, have shamans in their community who use drums to contact the spirit world.



### CONFUCIANISM

Confucius was a Chinese philosopher (551–479 BCE) who stressed the importance of respecting elders, acting dutifully toward the family and state, and honoring ancestors. His writings include the *I Ching*, which is used for telling the future.



### ABORIGINAL RELIGION

Australian Aborigines traditionally believe that the land, the sea, animals, and plants were created by ancestor spirits. These spirits, which live in a hidden world called the Dreamtime or the Dreaming, continue to give life to our world. Stories and songs about the Dreamtime have been passed down from generation to generation for thousands of years.



# Celebrations

Celebrations are an incredibly important part of religious, public, and family life. They bring people together, give people something to look forward to, and generally encourage joy and high spirits.

### TELL ME MORE...

**Chinese calendar** In the Chinese calendar, each year is named after one of the 12 animals of the Chinese zodiac: rat, ox, tiger, rabbit, dragon, snake, horse, goat, monkey, rooster, dog, or pig.



### LENT

■ Lent is a Christian festival that lasts 40 days and 40 nights and leads up to Easter. Traditionally, it is a time for fasting and praying as Christians remember the 40 days Jesus spent in the wilderness.



### FAMILY CELEBRATIONS



■ Family is an important part of human life, and families all over the world get together to celebrate events such as new babies, birthdays, or weddings.



### CHINESE NEW YEAR



■ **Where** China and Chinese communities across the world.  
■ **When** It begins with the new moon on the first day of the new year, which falls in January-February, and ends on the full Moon 15 days later.  
■ **What happens** Everyone hangs lanterns in their windows and dragon dances are performed in the streets. Families celebrate with a special meal and honor their ancestors. Red clothes are worn, which represent happiness.  
■ **What it's celebrating** New beginnings and the sowing of new crops.



### DIWALI

■ **Where** India, and celebrated by Hindus all over the world.  
■ **When** Within the months of Asvina and Kartika (October/November).  
■ **What happens** Diwali is the Festival of Lights. People light small lamps (diyas) and put them around their houses and gardens. They give each other gifts of candies and let off fireworks.  
■ **What it's celebrating** Diwali celebrates the return of Lord Ram from exile and his crowning as king. According to legend people lit lamps to light his way in the darkness. The Diwali lights also represent the "inner light" within people, their true essence or soul.



### RIO CARNIVAL



■ **Where** Rio de Janeiro, Brazil  
■ **When** Carnival goes on for four nights in February, just before the beginning of Lent.  
■ **What happens** Everyone takes to the streets in carnival clothes, they dance or ride on huge floats. The highlights of the carnival are a competition between samba schools and parading in amazing costumes in the sambadrome.  
■ **What it's celebrating** Pre-Lent fun





## FASNACHT (CARNIVAL)

- **Where** Austria, Germany, Alsace (France), and parts of Switzerland.
- **When** The day before Ash Wednesday—the last Tuesday before Lent.
- **What happens** Families gather together for a feast and many areas have processions to welcome in the springtime. Honored members of a town dress up as the carnival prince and peasant. Everyone else dresses up in anything from clown costumes to witches or even fruit!
- **What it's celebrating** It's a time of celebration before the self-denial of Lent. It also goes back to pre-Christian times, when it was a way to drive out the evil spirits of winter and encourage spring and good crops.



## DAY OF THE DEAD



- **Where** Mexico
- **When** November 1 and 2
- **What happens** People build altars in their homes, covered with photos and possessions of their dead relatives to guide the loved ones home.
- **What it's celebrating** Relatives who have died, but still live on in the memory. People believe that on the Day of the Dead it is easier for souls of the departed to visit the living.



## WINTER CARNIVAL QUEBEC



- **Where** Quebec City, Canada
- **When** Last weekend of January until mid February.
- **What happens** It's the largest winter carnival in the world. People get together to enjoy night parades, concerts, dogsled rides, and snow sculpture competitions.
- **What it's celebrating** It's a rowdy get-together to eat, drink, and have fun before Lent begins.



## THANKSGIVING

- **Where** United States
- **When** 4th Thursday of November
- **What happens** Families gather together for a feast and traditionally eat turkey, stuffing, and pumpkin pie.
- **What it's celebrating** Thanksgiving Day is a holiday in the US. People celebrate the successful harvest early European settlers of the country experienced in 1621. The settlers were taught by Native-American Indians to share of the natural abundance of the Earth by caring for crops, hunting, and fishing.



▲ **FIRST THANKSGIVING** *The Indians joining in the feast of the New England Pilgrims.*

## CHRISTMAS



- **Where** North America, Europe, Australasia, and by Christians around the world.
- **When** December 25
- **What happens** Families get together to go to church, give each other presents, and to eat traditional foods such as roast turkey and panettone.
- **What it's celebrating** The birth of Jesus Christ.



Panettone

## HALLOWEEN



- **Where** US, Canada, and across Europe.
- **When** October 31
- **What happens** Children go "trick or treating," often dressed up as witches or skeletons. People carve faces in pumpkins and light candles in them.
- **What it's celebrating** Halloween was based on pagan customs when Celtic people lit bonfires before winter, but it has come to mean the evening before the Christian festival of All Saints Day.



# World art

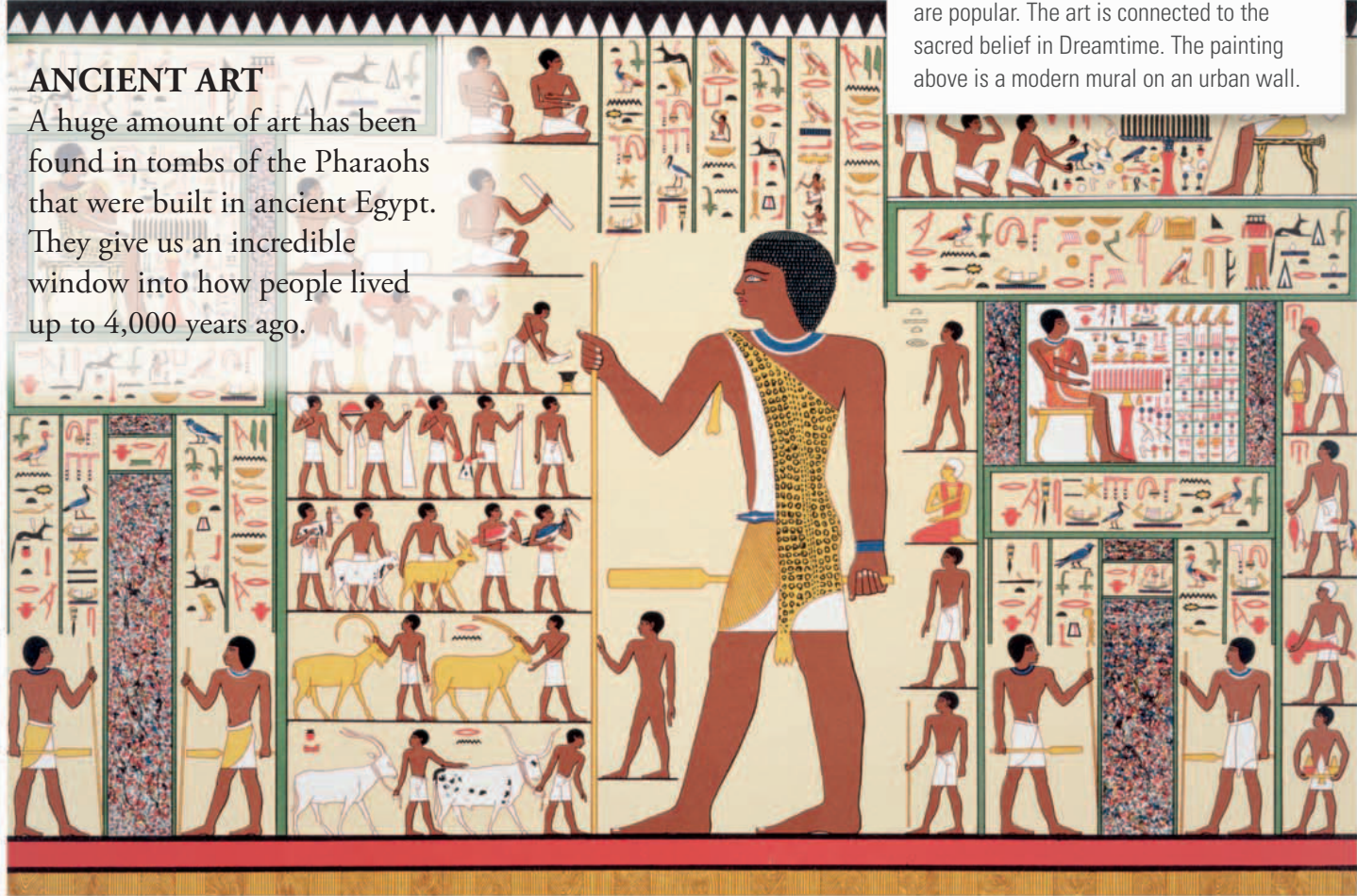
Art tells us an enormous amount about the history and culture of people. We can tell what people did in everyday life and what they wore through their art. We can learn about their religious beliefs, their sports, and their skills.

CULTURE



TAKE A PICTURE

Australian Aboriginal art dates back many thousands of years, and contemporary pieces are popular. The art is connected to the sacred belief in Dreamtime. The painting above is a modern mural on an urban wall.



## ANCIENT ART

A huge amount of art has been found in tombs of the Pharaohs that were built in ancient Egypt. They give us an incredible window into how people lived up to 4,000 years ago.

## The art of the Aztecs

In the 15th century the Aztecs created a short-lived empire that was destroyed soon after the Spanish invasion of 1519. They produced jewelry in gold, jade, and turquoise, as well as ceramics and textiles with angular, geometric patterns.



## Cave galleries

A series of famous Paleolithic paintings in the Altamira cave near Santillana del Mar, northern Spain, were developed over some 20,000 years, as descendants added to them.





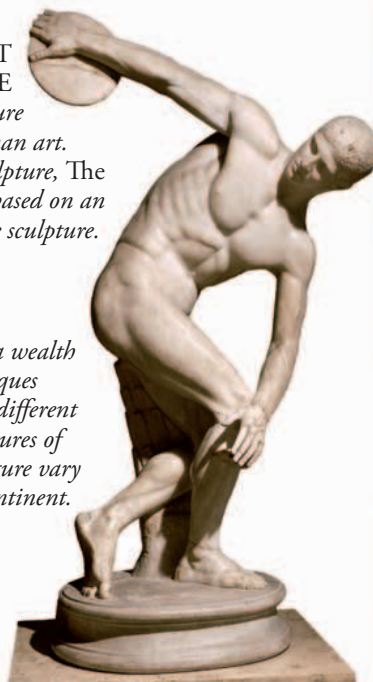
**Terra-cotta army**

In 1974, one of the most extraordinary pieces of art ever found was discovered by farmers. It was a huge army of Chinese warriors made out of terra-cotta pottery. In time, archeologists found more than 8,000 life-size statues guarding the tomb of the first emperor of China, Qin Shi Huang, who ruled from 221–210 BCE. Some of the warriors even have horses.



▶ ANCIENT SCULPTURE

*Ancient Greek sculpture heavily influenced Roman art. This Roman marble sculpture, The Disc Thrower, was based on an original Greek bronze sculpture.*



◀ AFRICAN SCULPTURE

*African art covers a wealth of styles and techniques used by the many different cultures. Sculptures of the human figure vary across the continent.*

**Art imitating life**

The ancient Greeks were interested in ideals—statues that showed a perfect body. The ancient Romans were influenced by Greek art, but they were more interested in portraiture: statues that looked like a particular person, especially someone famous. They believed that having a good image of somebody's face kept its ghost happy.

**Religious art**

Many pieces of art depict religious scenes. They might present religious figures from history, or religious symbols and traditions. The artists often used gold leaf (thin sheets of gold) and rich reds.

**RUSSIAN ICONS**

*Icons are images or representations of a religious figure. They are mainly painted in the symbolic style of Byzantine art.*

**SOUTH ASIAN ART**

*Thangkas (embroidered banners) and mandalas (diagrams) are often used for meditation. They have detailed patterns to convey spiritual ideas.*

**Sculpture**

Sculpture has been around since prehistoric people carved shapes into rock. While early peoples sculpted religious decorations and icons, the ancient Greeks made lifelike statues.

**TAKE A LOOK: COLORS FROM NATURE**

Before we could buy paints, people had to make colors from nature. They often used crushed rocks, minerals, plants, or insects. They mixed the powder or juice with egg yolk or animal fat to make paint. Over the centuries, artists have found their perfect color in all kinds of strange ways.



**White**—from chalk

**Black**—from charcoal

**Golden Indian yellow**—from the urine of cows that had been fed mango leaves

**Deep red**—sometimes from the crushed and dried bodies of female scale insects (*Dactylopius coccis*)

**Green**—from the juice of parsley flowers

**Brown**—from the inner bark of the oak tree (*Quercus tinctoria*)

**Dark violet**—from crushed elderberries

**Dark brown**—from the ink of a small squid called a cuttlefish (*sepia officinalis*)



# Modern art

*Four Ballerinas on the Stage*  
by Edgar Degas

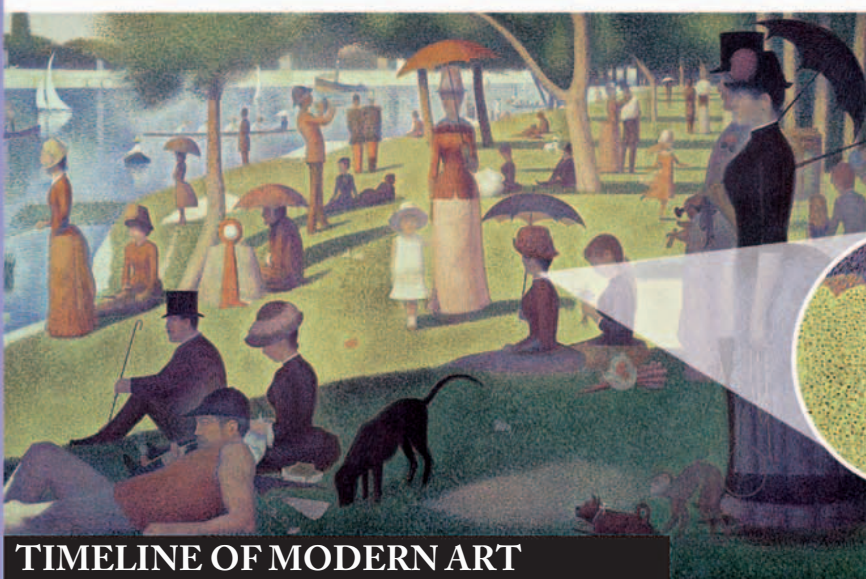
Modern art is difficult to describe because these days “anything goes,” from a beautiful oil painting to wrapping a building up in fabric or making a picture out of elephant dung. Some specific styles have emerged and many of these were controversial at the time.

## IMPRESSIONISM

In the 1870s, a group of artists broke away from painting religious or historical subjects and instead painted everyday scenes in a new style. These impressionists often painted outdoors, aiming to capture the impression of light and create a snapshot of real life. The group included Édouard Manet, Claude Monet, and Edgar Degas.



◀ **THE TECHNIQUE** Short brushstrokes of pure color gave a sketchy, patchy, spontaneous painting that suggests a fleeting moment in time.



**POINTILLISM** Georges Seurat invented a technique called pointillism. He used tiny dots of pure color that, when standing back, seem to merge to make new colors. This is known as optical mixing.



◀ **THE TECHNIQUE** From a distance, this lady's hat looks red. But it is actually made up of red, green, yellow, and blue dots.

*Sunday Afternoon on the Island of La Grande Jatte*  
by Georges Seurat

## TIMELINE OF MODERN ART

**1860s–1890s**  
Impressionism began in France when artists tried to capture a fleeting moment.



**1880s–1905**  
Postimpressionist artists, including Paul Gauguin, Paul Cézanne, and Vincent Van Gogh, painted vibrant, bold, and often personal pictures.

**1880s**  
Pointillism is a form of art where paintings are made up of dots of color.

**1880s–1890**  
The work of Expressionist artists including Edvard Munch conveyed people's feelings, such as joy or sorrow.

**1907–1920s**  
Cubism is a form of art that shows several different views of an object at once.

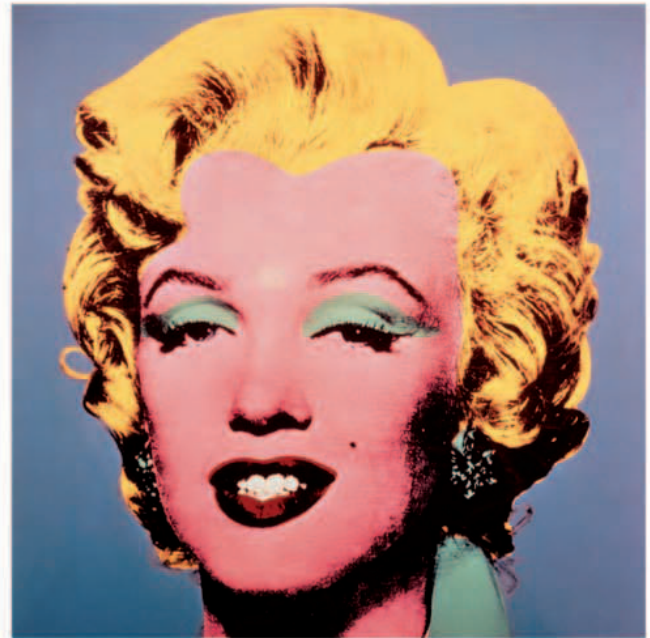


## CUBISM

Pablo Picasso, probably one of the most famous modern artists, experimented with space by breaking pictures up into distorted and weird shapes. *Three Musicians* looks like a mixed-up picture but the instruments the musicians are playing can be seen. This style is called Cubism. It shows a scene from several different points of view all at once.



*Three Musicians* by Pablo Picasso



## POP ART

A new popular culture emerged with television, pop music, and movies in the 1950s and 1960s. Pop Art became the new movement and artists made simple, brightly colored prints of popular images, such as soup cans and movie stars, that could be printed again and again.

▲ *In the 60s, Andy Warhol celebrated popular figures with colorful screen-print portraits. This one is Marilyn Monroe—he produced similar images of Elizabeth Taylor, Elvis Presley, and Jackie Kennedy.*

## ART TODAY

Today, artists are experimenting as much as ever, pushing the boundaries and finding new techniques. New Media artists use people's possessions and record people's emotions and reactions using the new digital technologies.



◀ **NEW MEDIA** *David Hockney has taken many photographs and stuck them together to make a bigger picture.*



▲ **INSTALLATIONS** *Tracey Emin transported the beach hut where she met her boyfriend into an art gallery.*

### 1910–1950

Abstract art distorts the shape and color of subjects. Jackson Pollock made pictures by splashing paint over a canvas on the floor.



### 1920s

Surrealist artists, including Salvador Dali and René Magritte, began to paint in a dreamlike style. This is Magritte's 1964 self-portrait *The Son of Man*.



### 1950s–1960s

Pop art uses ideas and images from popular culture, such as food packaging, comics, or famous people.

### 1970s–MODERN DAY

Modern art experiments with new media. Dressed in suits, Gilbert and George Del used themselves in their art as “living sculptures.”





# Writing and printing

Imagine a life without books, newspapers, comics, magazines, menus, letters, and emails—it would be a very different place. Writing gives us news, entertains us, and, more importantly, documents history and teaches and spreads ideas. Printing allows one person's ideas to be communicated to millions of people at the same time.

## ANCIENT WRITING

The earliest form of writing didn't use letters, but pictograms—symbols that each represent a single word or sound. Some of the earliest writings are from ancient Egypt. Known as hieroglyphics, these pictograms have been traced back 5,000 years. Nearby, in Mesopotamia, people started to keep accounts about taxes and crops using cuneiform script on clay tablets.

▼ *Cuneiform script was carved into wet clay using a blunt reed. Pictograms became simplified into wedge-shaped markings.*



◀ *Hieroglyphics on the Temple of Hathor, Egypt.*



### Methods of writing

Modern pens are very different from the original methods of writing, such as reeds for carving clay, or a quill (bird feather) dipped in ink for writing on animal hide. The Romans used lead pencils 2,000 years ago, but the graphite pencils we use today were invented in England in the 1500s. But some traditions remain: Japanese script is still written with a brush and ink.

## TAKE A LOOK: WRITTEN LANGUAGE

There are about 6,800 different languages spoken in the world today and many of them have their own letters or characters when written down. Although there are many localized styles of writing in the world, there are five main types that dominate.



▲ *CHINESE is one of the oldest written texts in the world. It uses pictograms called characters.*

▲ *LATIN writing evolved about 2,600 years ago. It is the most widely used alphabet in the world.*

▲ *BENGALI script is syllabic—rather than letters, it has symbols for consonants and vowels.*

► *CYRILLIC is used by many Slavic people (in eastern Europe), such as Russians. It is thought to have evolved from the older Greek script.*



◀ *THE ARABIC ALPHABET just uses consonants, vowels are indicated by signs above or below the consonants. Arabic is read from right to left.*



## PRINTING

The Chinese first invented printing by blocks in the 7th century. A word or whole page was carved onto a wooden block, which was dipped in ink and printed onto cloth. The block could be dipped and printed again and again, but each print had to be done by hand.



▲ **BAD MOVE** In 1045, Chinese printer Pi Sheng invented movable type. Each block was carved with a character, and blocks could be rearranged to make new pages. But with thousands of characters, it didn't really work.



### ◀ THE GUTENBERG PRESS

Four hundred years after Pi Sheng, in 1455, Johannes Gutenberg of Germany invented the mechanical printing press, which used metal movable type. For the first time in Europe, books could be mass-produced, with the Christian Bible being one of the first.



**WOW!**

Every day, millions of newspapers are printed all over the world. Japanese newspaper *The Yomiuri Shimbun* has the highest circulation in the world, with an estimated 10 million readers each day.

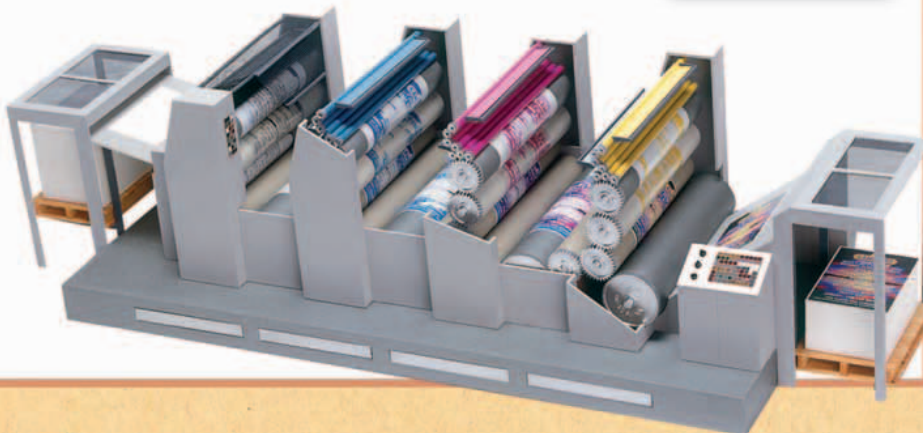
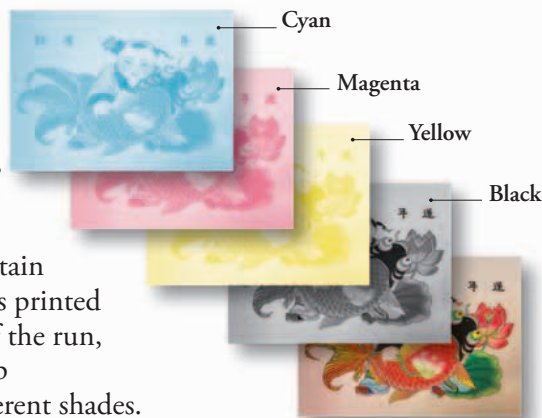
### How do presses work?

Like the earliest hand printing, presses use blocks carved in relief—with reversed, raised letters that print the right way around. Letter blocks, called “type,” are set into a frame and covered in ink, and the paper is pressed down on top.

### Color printing

How many colors can you see on this page?

Technically, there are just four: cyan (C), magenta (M), yellow (Y), and black (K). As the paper runs through the CMYK printing rollers, a certain amount of each colored ink is printed onto the paper. At the end of the run, the layers of ink have built up to produce thousands of different shades.



### BEST-SELLERS

The most popular books in the world are known as best-sellers.

- The biggest seller of all time is the Christian Bible, at an estimated 6 billion copies. It has been translated into 2,000 languages.
- Mao Zedong's *Quotations from Chairman Mao* sold some 900 million copies.
- The seven *Harry Potter* books by J. K. Rowling have sold more than 500 million copies worldwide.
- *Le Petit Prince (The Little Prince)* by Antoine de Saint-Exupéry has sold more than 80 million copies.
- Beatrix Potter's *The Tale of Peter Rabbit* has sold 45 million copies worldwide.



# Education

It's an essential part of culture to pass on knowledge to the next generation. In most countries, this knowledge is taught in school. What you learn in the classroom and beyond gives you the skills that you will need for the future. Without education, you would not be able to read this book.



▲ **SCHOOL UNIFORM** Many schools around the world have surprisingly similar uniforms. Some schools have unusual extras as part of their uniform—children who live near the Sakurajima volcano in Japan have to wear hardhats to school because the volcano hurls rocks daily onto the nearby town.

## IN SCHOOL

Children have been going to school for thousands of years. Archeologists discovered a school building in the ancient city of Ur (in modern-day Iraq)—a city that died out 2,500 years ago. School hasn't changed very much since then. Across the world, children still sit together in classes to be taught lessons by a teacher.

### TELL ME MORE...

Millions of children around the world cannot go to school. This is especially true in poor parts of the world, where there are places without schools and teachers. Some families can't afford to pay for schooling, so children have to work or are kept at home to help.



### TAKE A PICTURE

Pens and books are taken for granted in most schools—but in the developing world, there might not even be one book per class.

**A CLASS APART**  
Not all schools have the same facilities. While computers are used in most American schools, this primary school in Senegal, Africa, has no electricity.



**What's on the schedule?** Right now, somewhere across the other side of the world, a child is being taught English, math, and sports, just like you. But children from different countries may learn things specific to their culture in their school. For example, some boys in Mongolia attend monastery schools to learn to be Buddhist monks. They also study nature, medicine, and art.



▲ HAKA Students in New Zealand learn an important traditional Maori dance, the Haka.

**Home schooling** Lots of children around the world are taught at home by their parents or tutors. Around 1 million children in the United States are home-schooled, but in some countries, such as Brazil, Germany, and Hong Kong, it's illegal not to go to a formal school. Hundreds of children in remote, rural parts of Australia live so far away from the nearest school, it is impossible for them to go to school. Instead, they learn through *The School of the Air*, making online or radio contact with a teacher.



▲ SCHOOL OF THE AIR A pupil is guided through an online class at home.

## TAKE A LOOK: TEACHING TRADITIONS

Community education is especially important when it comes to passing



▲ WEAVING A Marsh Arab mother teaches her girls a skill they will use to make clothes and rugs, and earn money.

down cultural traditions, and most of this is done outside of school.



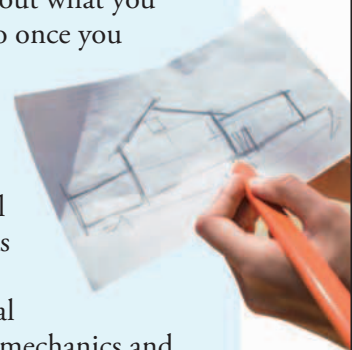
▲ HERDING A Nenet boy spends nine months a year at boarding school, and three months at home learning caribou herding.

**Always learning** Education isn't just about math and spelling: you learn many other things in school, possibly without even realizing it. When you play sports, you are learning how to stay healthy, how to be part of a team, and how to compete. When you study history, geography, and religion, you learn about people and the different ways of life around the world. And when you interact with your classmates and teachers, you learn how to develop relationships.



▲ PLAYING SPORTS These children aren't just learning the rules of soccer, but also how to stay fit and healthy.

**What happens next?** Have you ever thought about what you would like to do once you leave school? Some careers require a college degree and professional licensess, such as architects and lawyers. Practical careers, such as mechanics and hairdressing, might offer apprenticeships—"on the job" training where you work with (and so learn from) someone who is already doing that job.



**It doesn't stop here!** Education shouldn't finish just because you've graduated high school. Going on to college improves your chances of getting a job, and as you get older it's important to keep your brain active to stay healthy. Lots of people attend evening classes to brush up on old skills or learn entirely new ones.



**WOW!**

One out of every seven people in the world cannot read. If people can't read, write, or do math, it will affect their whole lives. But education can help people escape poverty: children who go to school get better jobs when they are older, live longer, and are healthier.



# Music

Everyone enjoys music in some form, whether they choose to play an instrument, or sing, or simply listen. Music brings people together at all sorts of events.

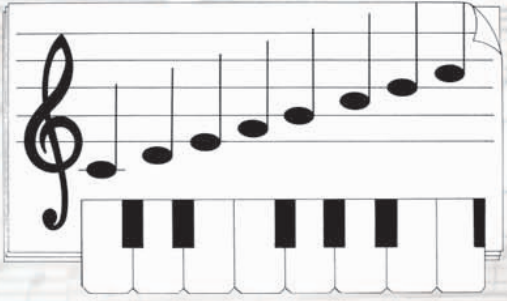


▲ THE FIRST MUSIC We know that music has been played and enjoyed for thousands of years because ancient drawings have been found showing musical instruments.

## NOTATION

The most common way to write music today is the five-line notation using dots, symbols, and abbreviations. It is based on a system used by Roman Catholic monks in the 10th century. When you learn a musical instrument, you learn to read music at the same time.

**Pitch** is how high or low a note sounds. Notes are grouped into sets of eight, known as an octave and written on five lines called a **stave**.



The "clef" shows what notes are on the staff. This is the treble clef.

The "key signature" shows which key the music is in.

The speed of the music, or "tempo" is often written in Italian. *Allegro* means "quickly."

All music is divided into equal measures, called "bars," each of which has the same number of beats.

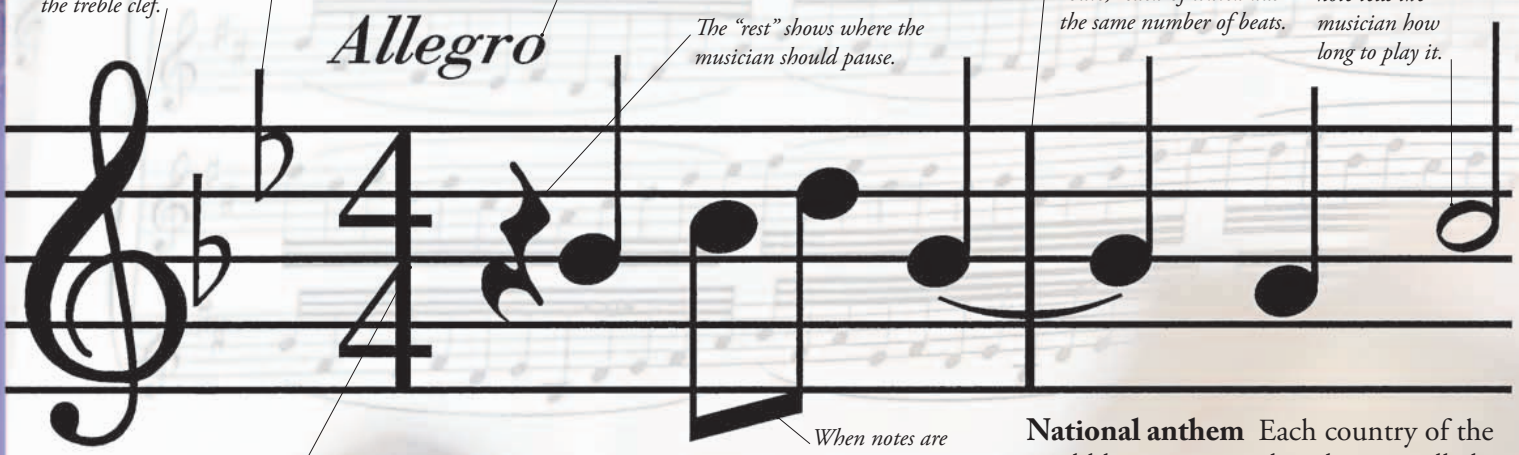
The shape of each note tells the musician how long to play it.

The "rest" shows where the musician should pause.

When notes are next to each other their hooks are sometimes joined together.

The "time signature" shows the musician the number of beats to a bar.

*mf* Dynamic markings indicate how loud to play the music. "mf" means moderately loud.



**National anthem** Each country of the world has its own cultural song, called their national anthem. They are often sung at important national occasions, including sporting events.

**TELL ME MORE...**

When musicians in an orchestra perform together, they need to make sure they play their notes at the right time. The conductor is the organizer of the orchestra who directs using visible gestures.



► THE SOUTH AFRICAN national anthem includes five of the eleven official national languages including Afrikaans, English, and isiZulu.





## ◀ FOLK MUSIC

*A country or an indigenous people often have their own style of music and dance, known as folk music.*



## ▶ RELIGIOUS MUSIC

*Music is used a lot in religious worship around the world, whether in song, like this Christian choir singer, or using instruments like these Buddhist monks.*



## SOUND OF THE PEOPLE



A type of music can often be unique to the culture of a nation or people.

■ **The didgeridoo**, an Aboriginal instrument from Australia, is considered to be one of the oldest wind instruments in the world. It is often used in Aboriginal ceremonies.

■ **The sitar**, a stringed instrument, is the best-known of all Indian sounds.

It has extra strings that lie beneath the main strings that vibrate to give it its shimmering sound.

■ **The djembe drum** is a goblet-shaped wooden drum covered in a skin that is played by hand. The drum originated in west Africa and is still an important part of the culture in many west African countries. The rhythmic beat is often used in dance.



## MUSIC STYLES

Music changes all the time, reflecting how each new generation feels and reacts to an ever-changing world.

■ **Classical music** is a general term for music written to be performed in a concert hall. Often it is composed for an orchestra, for a choir or for opera.

■ **R&B** or rhythm and blues was originally performed by African-Americans in the 1940s. It was a mixture of religious gospel music and blues (slow melancholy songs). R&B has evolved over the decades into soul and funk-influenced pop music.



■ **Jazz** originated in the early 20th century in the US. It was a blend of African slave music played with European instruments. The saxophone, trumpet, and double bass are three of the key sounds in jazz bands.

■ **Rock'n'roll**

In the 1940s and 50s in the US a whole new sound emerged with bands using electric guitars, bass guitars, and drums; this was known as rock'n'roll.

■ **Rock music**

emerged in the 1960s and includes lots of different styles from punk rock to heavy metal.



■ **Reggae** originated in Jamaica in the 1960s. Reggae has a slow, rhythmic style and is often associated with the Rastafarian religion.

■ **Country music** is a blend of traditional music from the Southern states of the United States, and rock'n'roll. It is one of the biggest-selling styles of music today.



■ **Dance** The dawn of the computer age and highly developed synthesized sound led to a new sound designed to fill dance floors. DJs mixing music using turntables live on the dance floor have become big stars in themselves.

■ **Pop music**, or popular music, is not a particular style of music, but music that is made popular by people buying it, playing it on the radio, or paying to see it performed live. Pop music is designed to sell and do well in the pop charts.





# The orchestra

An orchestra is a collection of about 100 musicians who play different instruments that are grouped into strings, woodwinds, brass, and percussion. Each instrument plays a different part to make one piece of music.



## TAKE A PICTURE

Antonio Vivaldi (1678–1741) was born and raised in the Republic of Venice. He composed music in the Baroque style. His most well-known piece is *The Four Seasons*, in which he tried to capture the atmosphere of each season.

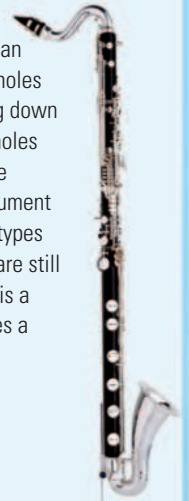
## PERCUSSION

■ Percussion instruments are hit, banged, scraped, or shaken. When you bang a percussion instrument, such as a drum, its surface vibrates, making the air inside ring with sound. This sound adds a beat or drama to a piece of music. Cymbals also vibrate to produce sound—they are clashed together in a swinging, brushing movement during the climax in orchestral music.



## WOODWIND

■ Woodwind instruments make sound when air blown into them vibrates. Players can alter the sound by covering holes with their fingers, or pushing down on metal “keys” that cover holes the fingers cannot reach. The clarinet is a woodwind instrument and there are more than 12 types of clarinet, although not all are still in use. The one shown here is a bass clarinet, which produces a deep, mellow sound.





## CONDUCTOR

■ A key figure in most orchestras, the conductor directs the musicians using hand and arm gestures.



## TAKE A LOOK: SHEET MUSIC

Each member of an orchestra has their music written down in front of them as sheet music. The modern five-line written notation, widespread by the seventeenth century, was developed from a system of dots used by Roman Catholic monks in the tenth century.



▲ EARLY MUSIC NOTATION  
*This piece of music is the original score for Beethoven's Moonlight Sonata, finished in 1801.*

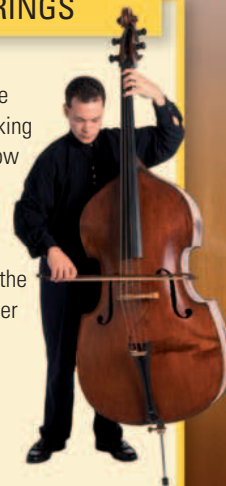
## BRASS

■ Brass instruments are long tubes that open into a bell shape at one end. To play them, the musician blows into the mouthpiece. Long tubes, such as that on a trombone, sound deep. Shorter tubes, such as that on a horn, sound higher. In addition to air, lots of liquid is blown in. This is let out through the spit valve.



## STRINGS

■ String instruments are played by plucking or running a bow across the strings. The double bass shown here is the deepest member of the string family. The thickest string produces the lowest note.





# Let's perform

Everyone enjoys the spectacle of a show, be it a play, an opera, a movie, or a dance. What these performing arts have in common is that they communicate between people, and reflect their time and their culture.

## DANCE

Everywhere in the world, people love to dance. A dance can be a performance, part of a religious ritual, or something to do for fun. Most dances happen in time to music or a beat.

► **SALSA** *This popular form of dance probably originated in Cuba in the mid-20th century.*



▶▶ FAST FACTS ▶▶

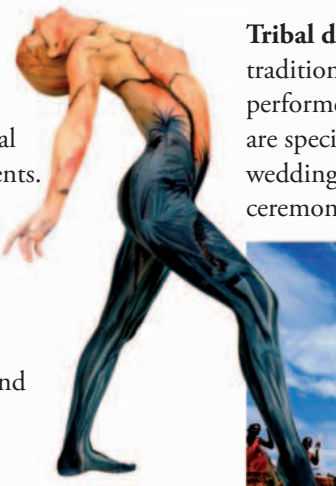
- The oldest known play was written by Thespis 2,500 years ago.
- William Shakespeare wrote about 38 plays in the 16th century, and they are still performed today.
- The first animated cartoons were made in the late 1920s. Mickey Mouse starred in one called *Steamboat Willie* in 1928.
- *The Ring Cycle* (*Der Ring des Nibelungen*), a series of operas by German composer Richard Wagner, takes 18 hours to perform.
- In the Middle Ages dancing was thought to help cure people suffering from seizures or spider bites.

**Street dance** is any dance that people have created for themselves, instead of being formally invented. Types of street dance include break-dancing and tango.

**Religious dance** *Bharatanatyam* is a Hindu dance performed by women. It is the national dance of India. The steps are incredibly precise—skilled dancers flow from pose to pose with complex movements of the feet, hands, arms, neck, head, and even the eyes!



**Ballet** requires great strength, skill, and grace, and it involves very specific and formal positions and movements. Classical ballets like *Swan Lake* and *Giselle* feature only these traditions, while modern ballets (right) are often much freer and more expressive.



**Tribal dance** is important in many traditional cultures. Dances are usually performed to the rhythm of drums and there are special dances for all kinds of occasions—weddings, funerals, harvests, hunts, religious ceremonies, and even to prepare for war.





## THEATER

People have been taking to the stage for thousands of years, performing everything from comic and tragic plays to pantomimes, operas, and musicals. The oldest plays were performed in ancient Greece and included song and dance as well as acting. Some of their outdoor theaters still stand today.



◀ **THE LION KING** is a musical play based on the animated feature film by Walt Disney.



### TAKE A PICTURE

Shadow plays use puppets and clever lighting behind a fabric screen. The traditional shadow theater of Indonesia, Wayang Kulit, is thought to be over 800 years old.

## WOW!

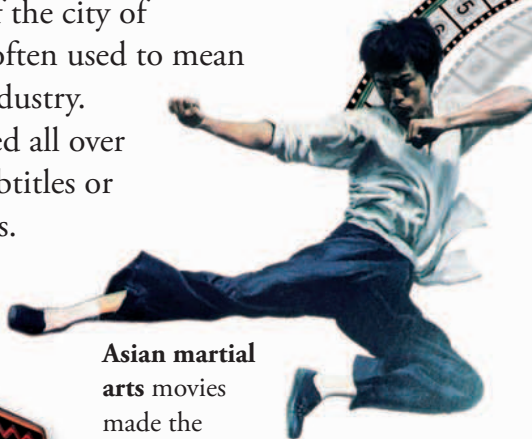
An average Hollywood feature film is just over 100 minutes long and uses 10,000 ft (3,000 m) of tape, wound onto five double reels.



## MOVING PICTURES

In 1895, the Lumière brothers astounded audiences with the first “movies,” and cinema has been a popular form of entertainment ever since. Movies are made up of a sequence of still images, which create the impression of movement when they are shown in rapid succession.

**HOLLYWOOD** is a part of the city of Los Angeles, but the word is often used to mean the whole American movie industry. Hollywood movies are watched all over the world, sometimes with subtitles or “dubbed” into other languages.



**Asian martial arts** movies made the names of stars like Bruce Lee. They are famous for elaborate stunts and fight scenes, and increasingly for special effects.



**Bollywood** is the name used to describe the movie industry, which is based in Mumbai (Bombay), India. Bollywood films are produced in the Hindi language at a rate of about 1,000 a year. They usually include extravagant musical scenes.



# Sports

Sports are good for health, but, perhaps more importantly, many sports are team events and bring people together for competitive fun. After all, everyone likes to win!



## BALL GAMES



*Soccer is a typical team sport where 11 players try to kick the ball into their opponents' goal.*

▲ **SOCCER** is arguably the most popular sport in the world. People all over the world play it in schools and parks, on the streets, or wherever they can. Billions of people watch the Football World Cup, held every four years, and for many countries soccer has become part of their culture. Soccer fans are fiercely loyal to their local or national teams.

- **Tennis matches** are played either as singles, between two players, or doubles, between four players.
- **Cricket** is played by people in more than 100 countries. The best teams play in international test matches.
- **Table tennis**, or ping-pong, became an Olympic sport in 1988. It is popular around the world, with an estimated 300 million players.
- **Football** is different from European "football" (aka soccer). It uses a ball with pointed ends, players wear protective padding and are allowed to carry the ball to make passes.
- **Rugby** is played with an oval ball between teams of 15 players.



▲ **GOLF** is played using a club to knock a small ball into a hole in as few shots as possible.



▲ **VOLLEYBALL** is played between two teams of six players over a net. It was invented in the 1890s.



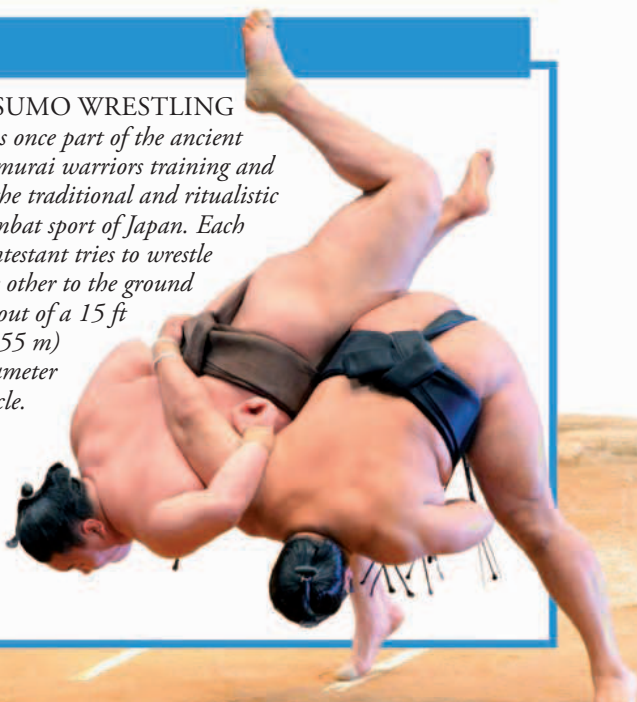
## CONTACT SPORTS

- **Fencing** contestants use lightweight blunt-tipped swords to hit target areas on their opponent's body.
- **Wrestling** dates back thousands of years. It is a form of hand-to-hand combat.

▶ **KARATE** is a Japanese martial art. It uses moves such as punching, kicking, and knee and elbow strikes.



▶ **SUMO WRESTLING** was once part of the ancient Samurai warriors training and is the traditional and ritualistic combat sport of Japan. Each contestant tries to wrestle the other to the ground or out of a 15 ft (4.55 m) diameter circle.



◀ **BOXING** is a tough sport, demanding huge upper-body strength. Boxers wear padded gloves.

- **Judo** first appeared in Japan in the 1800s, but developed from far earlier techniques.
- **Kung Fu Taolu** is China's national sport, where it is known as "wushu."



## EXTREME SPORTS



▲ **SKYDIVING** Skydivers usually leap from a small plane and freefall before opening a parachute to enable safe landing. Worldwide, there are more than 450 skydiving drop zones. Instead of a plane, some skydivers have jumped from helicopters or hot-air balloon baskets.

■ **Surfing** Surfers ride lightweight surfboards just ahead of a breaking ocean wave.

■ **Ski jumping** involves skiing down a steep hill, leaping, and landing safely.

■ **Hang gliders** use a triangular-shaped wing to glide through the air. They can stay up for many hours by finding rising air columns.

■ **Bungee jumping** sees people leap from a high spot and freefall to be saved by a strong elastic rope secured to their ankles.



◀ **EXTREME CLIMBERS** climb ice and rock faces that appear impossible.



◀ **BMX is bicycle motocross.** It involves spectacular jumps and hair-raising tricks.

## RACES

■ **Drag racing** is the fastest land-based sport. It originated in the US and takes place between two highly charged dragster cars.

■ **Speed skaters** can reach speeds of 40 mph (65 km/h).

■ **Horse racing** with powerful thoroughbred horses may be over flat ground or over jumps.

■ **Yachts** of all sizes are used for competitive racing.



▲ **FORMULA ONE (F1)** Grand Prix races are fast and exciting.



▶ **ROAD CYCLISTS** may cover huge distances in a race such as the Tour de France.



▲ **HURDLE RACES** are a major part of any athletic event. Competitors race over 10 hurdles spaced over a set distance. The sprint course is 100 m (328 ft) for women and 110 m (360 ft) for men. A longer course takes place over 1,300 ft (400 m), but with the same number of hurdles. Many schools enjoy hurdle races.



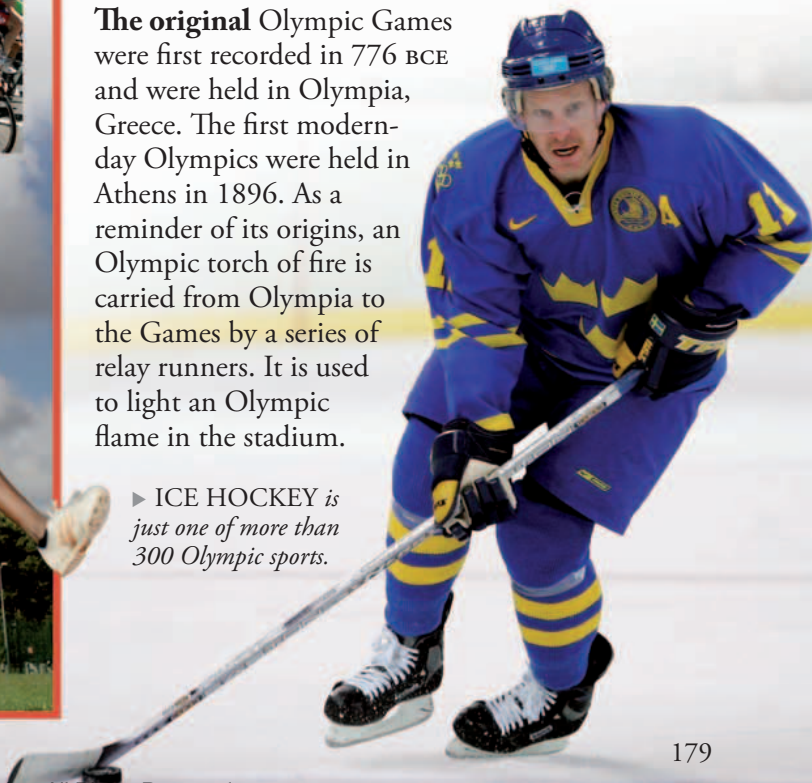
◀ **THE OLYMPIC RINGS** The interlocking rings represent the coming together of athletes from all over the world.

## OLYMPIC GAMES

The Olympic Games is the most important sporting event in the world. Every country is invited to take part—athletes from 204 countries took part in the Beijing Olympics in 2008. Winners receive a gold medal.

**The original** Olympic Games were first recorded in 776 BCE and were held in Olympia, Greece. The first modern-day Olympics were held in Athens in 1896. As a reminder of its origins, an Olympic torch of fire is carried from Olympia to the Games by a series of relay runners. It is used to light an Olympic flame in the stadium.

▶ **ICE HOCKEY** is just one of more than 300 Olympic sports.





# Architecture

Architecture is the design of buildings and other structures, such as bridges. An architect's job is to make sure a building is well built and safe and pleasant to use. It also has to be suitable for its purpose—theaters need room for a stage and dressing rooms, for example. Architects also try to make buildings look interesting and inspiring.



## GETTING STARTED

Before designing a building, architects need to know what the building is for, where it is to be built, and how much money can be spent on it. They then work out what the building will be made from and the position and measurement of every wall, door, and window, which they record in great detail on drawings called plans. Sometimes they make a scale model of the building, too.

## CHANGES IN STYLE

Every period of history is marked by its own style of architecture. This reflects changes in taste and fashion and new building techniques and materials. Most cities are a mixture of old and new buildings that show many different styles.



▲ ANTONI GAUDI was a Spanish architect with a distinctive style. His most famous work is the Sagrada Família, the unfinished cathedral in Barcelona, Spain.



▲ STILT HOUSES Some people who live along coasts and rivers build their houses on stilts to avoid flooding.



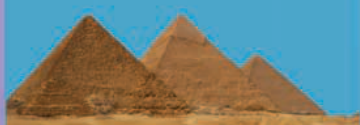
▶ BAMBOO HOUSES The Gamo people of Ethiopia make houses from split bamboo, which is woven and thatched.

**Ideal homes** People live in buildings that are suitable for the environment in which they live. Usually, they use local materials, such as wood and stone, or clay made into bricks. Some are even built into rocky hillsides or caves. The Inuit of the Arctic make temporary shelters from ice because there is nothing else to build with.

## TIMELINE OF ARCHITECTURE

### ANCIENT EGYPT

2590–2500 BCE  
Pyramids of stone erected in the Nile valley as tombs for kings.



### ANCIENT GREEKS

700–44 BCE  
Ancient Greeks built temples with specific proportions, known as the classical style.

### ANCIENT ROMES

200 BCE–500 CE  
The Romans used concrete to construct many large buildings and structures.



### BYZANTINE

330–1453  
Byzantine buildings are characterized by rounded domes on square bases and arches supported by columns.

### GOthic

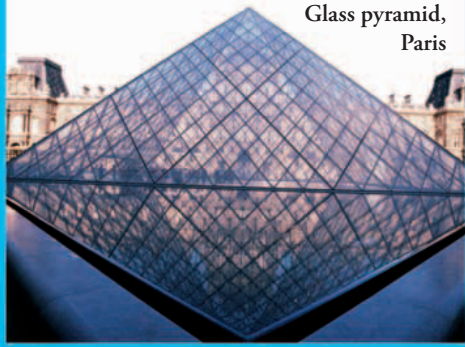
1100–1500  
Grand buildings of the medieval period feature pointed arches, ribbed vaulting, and flying buttresses to support high walls.





GLASS BUILDINGS

■ Traditional building materials include wood, stone, and brick, but many modern buildings make use of large amounts of glass. Although glass is fragile, new construction techniques involving steel or reinforced concrete frames have allowed architects to design light yet strong buildings.



Glass pyramid, Paris

TAKE A LOOK: DESIGN STYLES

Some structures are instantly recognizable because of their design. Every major city has a number of

famous buildings, but each has a different style according to the period in which it was built.



▲ TAJ MAHAL *This marble building is one of the finest examples of 17th century Indian architecture.*



▲ PALACE OF WESTMINSTER *When the original palace burned down in 1834 it was rebuilt in the Gothic style.*



▲ NATIONAL GALLERY, CANADA *The gallery is a striking modern structure of glass and granite.*

**Modern designs** Computers enable architects to design buildings that would not have been possible before. They can quickly work out if a shape can be built, and even allow the architect to walk around a virtual building.

▼ THE DESIGN of the Guggenheim Museum in the Spanish port of Bilbao is meant to resemble a ship.



CULTURE

BAROQUE

1650–1750  
The very grand, ornate style of Baroque design takes hold in Italy, France, and Spain.

SKYSCRAPERS

1890  
The first skyscrapers are built in Chicago, following the invention of the elevator.



ORGANIC ARCHITECTURE

1900–1940s  
Organic architecture, with its curved shapes inspired by nature, is promoted by American architect Frank Lloyd Wright.

Sydney Opera House



BAUHAUS

1919–1933  
The German Bauhaus school created designs based on clean lines, cubic shapes, and flat roofs.

ECO-LIVING

1980s onward  
Houses are built to be more energy efficient and use environmentally friendly materials.



# HISTORY AND POLITICS

- About one million years ago, early people began to spread out across the continents.
- Around 3000 BCE, Egypt became the first superstate.
- By 117CE, the Roman Empire stretched across western Europe and into Asia.
- China has the oldest continuous known civilization, lasting at least 4,000 years.
- In 622, Muhammad established the Islamic state in the Arabian Peninsula.



Why was Russia renamed the Union of Soviet Socialist Republics?  
*Find out on page 213*



What was rebuilt during the Ming Dynasty?  
*Find out on pages 194–195*





*Definition: History and Politics* is the study of the lives of people and the activity of governments and rulers in the past from written records.



- The United States Declaration of Independence was signed on July 4, 1776.
- By the 1900s, Great Britain's empire covered one-quarter of the Earth's land surface.
- World War I ended at 11 a.m. on the 11th day of the 11th month, 1918.
- In August 1945, atomic bombs were dropped on two cities in Japan, ending WWII.
- The United Nations was founded in 1945, seeking to achieve world peace.



? When did Mecca become the center of Islam? *Find out on pages 196–197*

? Which areas of the world are often in the news? *Find out on pages 214–215*





# Tales from the past

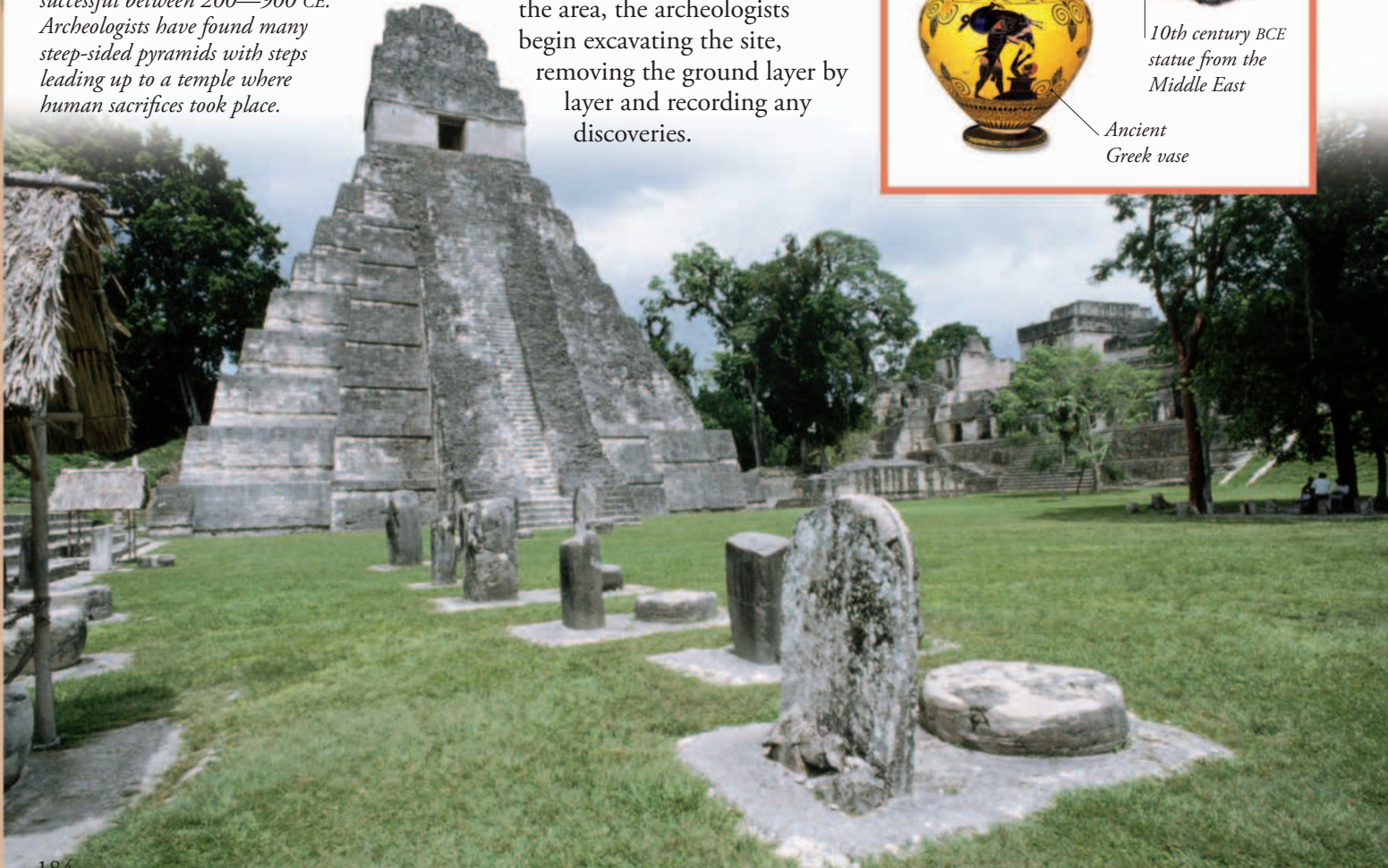
History is the study of things that have happened in the past. This can be anything from the earliest people to events of the last few years. A little like detectives searching for clues, historians look at evidence from the past known as primary sources.



**Digging for clues** The work of archeologists help historians to know more about early people. During their excavations of a site, archeologists uncover and study early buildings and find and examine artifacts—objects made by people from the past.

▼ **MAYAN RUINS** *The Maya civilization of central America was successful between 200—900 CE. Archeologists have found many steep-sided pyramids with steps leading up to a temple where human sacrifices took place.*

**Archeology site** After doing an aerial and surface survey of the area, the archeologists begin excavating the site, removing the ground layer by layer and recording any discoveries.



## STUDYING ARTIFACTS

- **What is the object made from?:**  
The artifact shows the materials available and the skills of the craftsmen.
- **Who would have used the object?:**  
The artifact may give clues about the status of people in society.
- **What was the object used for?:**  
Historians may be able to figure out what the culture and the way of life for the people was like from the artifact.





TAKE A LOOK: WRITTEN SOURCES

Since ancient times, official records of births, marriages, and deaths, census results, and tax records have been kept.



▲ **DOMESDAY BOOK** *In 1086, King William I of England commissioned a survey of every estate and village in the country.*

Many eyewitness accounts and inscriptions have recorded important events and the lives of famous people.



▲ **SOLDIER'S JOURNAL** *The diary of a US infantry soldier tells of his life during the Civil War (1861–65).*

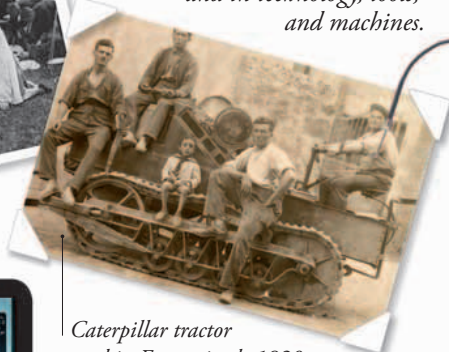
Other sources are the diaries and personal letters of ordinary people living through extraordinary events.



▲ **ANNE FRANK'S DIARY** *Between 1942 and 1944, a young Dutch Jewish girl wrote a diary while in a secret annex, hiding from the German Gestapo.*



▼ **AT WORK AND PLAY** *Photographs show the way of life and the changes in clothing styles and in technology, tools, and machines.*



*Caterpillar tractor used in France in the 1920s*



*Early 1900s folding roll-film camera*

**Old photographs** Since the mid-1800s, photography has become increasingly popular. Photos provide a visual source to historians studying the lives of people. Since recorded sound was developed, historians can also study oral accounts of people talking about their lives and reactions to events.



An X-ray of an Egyptian mummy

**New technology** Advances in technology have provided historians with lots more information about artifacts. Radio-carbon dating, X-rays, and thermal scans can reveal previously unknown details.

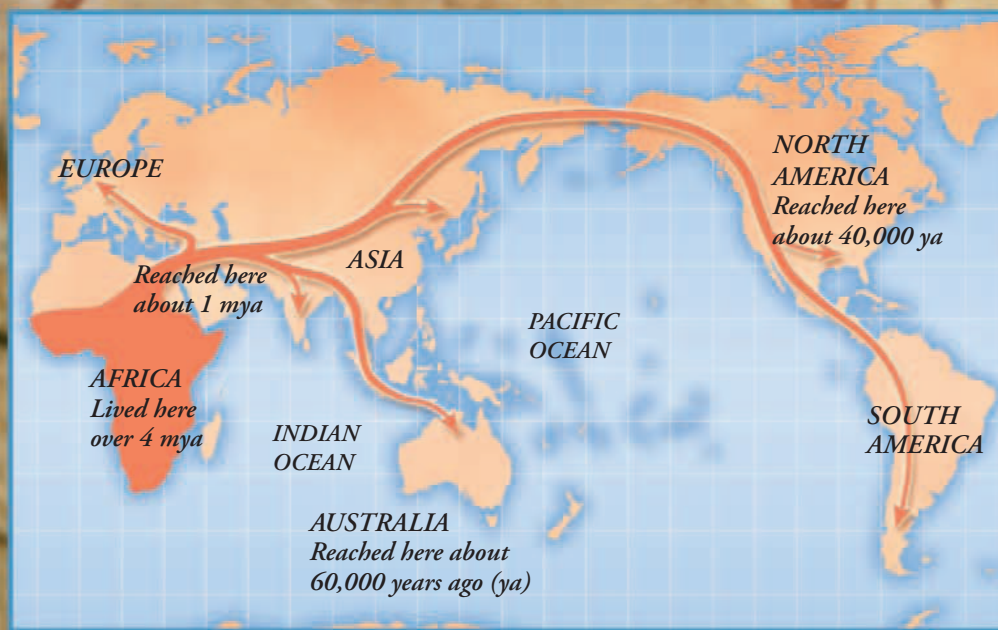
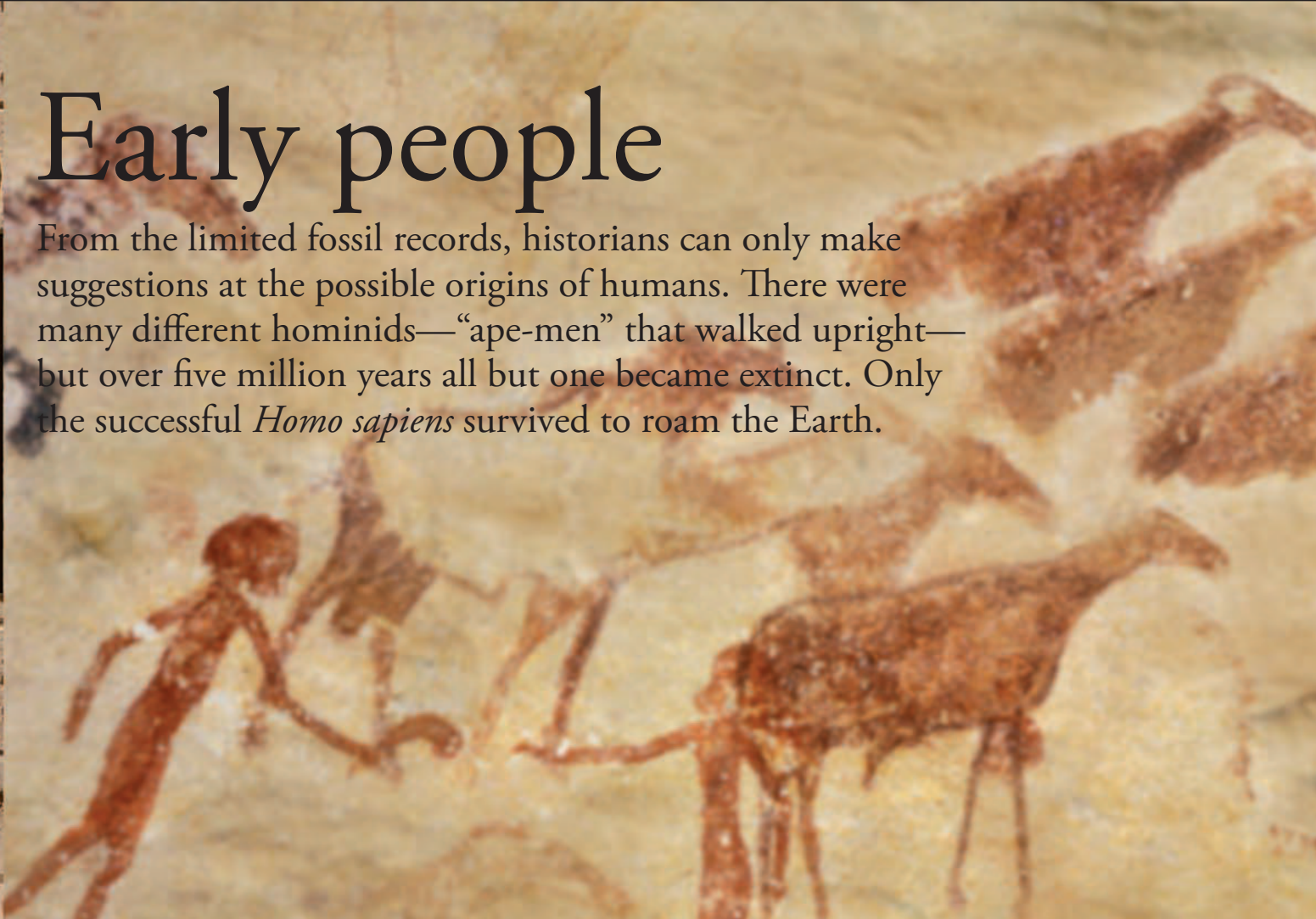


▼ **X-RAY EXAMINATIONS** *A medical X-ray of a 3,000 year old Egyptian mummy may reveal how the person died or more about the process of mummification.*



# Early people

From the limited fossil records, historians can only make suggestions at the possible origins of humans. There were many different hominids—“ape-men” that walked upright—but over five million years all but one became extinct. Only the successful *Homo sapiens* survived to roam the Earth.



## OUT OF THE FORESTS

Many historians think that more than five million years ago (mya), apelike creatures moved out of the forests of Africa to live on open ground. To survive, they learned to stand and walk upright to see farther and move quickly, leaving their hands free to carry possessions and learn new skills. About one mya, early people migrated out of Africa and spread out across the continents.

## TIMELINE OF HOMINIDS

### AUSTRALOPITHECUS AFARENSIS

Dated: over 4 mya  
Fossils found in Africa with very low forehead and projecting face.



### HOMO HABILIS

Dated: 2.3–1.6 mya  
Tools found with fossil remains that had large skulls.



### HOMO ERECTUS

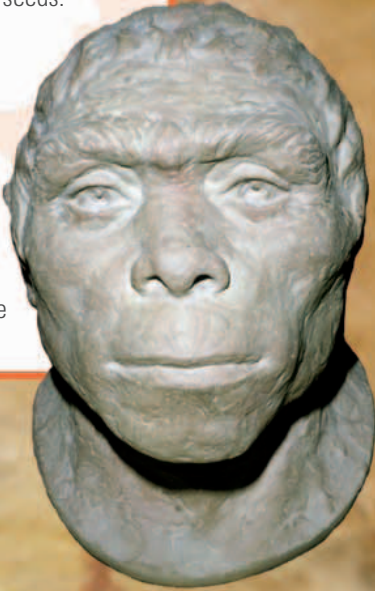
Dated: 1.8 mya–300,000 ya  
Fossils in Africa, Europe, and Asia found with long, low skulls and large molar teeth.





WHO'S WHO?

- **Lucy:** A female skeleton aged 25 years found in Ethiopia and estimated to have lived 3.2 mya. She was about 3 ft 6 in (107 cm) tall.
- **Nutcracker man:** Teeth and skull fragments found in Tanzania of a hominid estimated to have lived 2 mya. With the biggest, flattest cheek and thickest teeth enamel of any hominid, he ate only nuts and seeds.
- **Peking man:** One of 40 individuals found at a site in China and estimated to have lived 500,000–300,000 ya.
- **Old man:** A 30-40 year old skeleton with severe arthritis found in France. Estimated to have lived 50,000 ya, he would have had an average height of 5 ft 6 in (168 cm).



► **PEKING MAN**  
Historians have found evidence that the Peking man and his companions would have lived in caves, made tools, and used fire to keep warm and cook food.

TELL ME MORE...

As the early people moved northward, they had to cope with a colder climate and survive the ice ages. Clothes were first made from animal skins, but later, people discovered how to spin and weave wool.



TAKE A LOOK: STONE AGE

- **Paleolithic period:** People moved around following the herds and used clubs and sharpened stones to hunt.
- **Mesolithic period:** Hunters made bows and arrows and the gatherers made baskets for collecting fruits and nuts. People continued to move around.
- **Neolithic period:** People became food producers so were able to have a more settled lifestyle. They made wooden agricultural tools and developed new crafts, such as pottery.

▼ **FIRST TOOLS** Pieces of flint were shaped by chipping away flakes, leaving a sharp edge.



Pebble hammer for shaping flint

► **GATHERERS' TOOLS** Flakes of flint were attached to wooden handles. These tools were used to dig up edible roots and cut wood for fires.



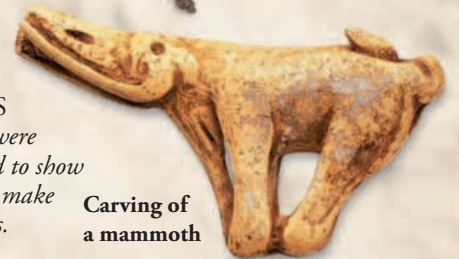
A spark was made by hitting an iron stone against a flint.

Bark for collecting fruits and nuts

◀ **HUNTERS' TOOLS** The metal tips of the arrows were dipped in poison made from beetle larvae.

Feathers

► **CARVINGS** Animal bones were skillfully carved to show pictures and to make small sculptures.



Carving of a mammoth

HOMO NEANTHERTHALENSIS

Dated: 250,000–30,000 ya  
Fossils found in Europe and Middle East with protruding jaw, receding forehead, and weak chin.



HOMO SAPIENS

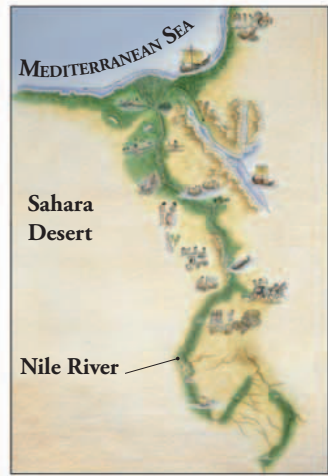
Dated: 100,000 ya to present  
Found all over the world, these skulls have a rising forehead, prominent chin, and light bone structure and can hold a large brain.





# Ancient Egypt

From about 6,000 years ago, cities began to appear along the banks of large rivers. The civilizations in Egypt and Mesopotamia (now Iraq) were the earliest. Around 3000 BCE, Egypt was unified to become the first superstate under the rule of a pharaoh (king).



**The Nile River** The first ancient Egyptians were able to establish farming communities in this otherwise desert landscape, all thanks to the Nile River. Annual flooding kept the land on either side of the river fertile and watered the crops.



**Tombs for the pharaohs**

Vast, towering tombs were built by the pharaohs for their journey to the afterlife to become a god. The largest pyramid of Pharaoh Khufu (reign 2589-66 BCE) took about 20 years to build and was made from over two million limestone blocks.

*Inside, passages led to burial chambers where the pharaoh was buried with his belongings.*

*One of the smaller pyramids for Khufu's wives*



**PYRAMIDS AT GIZA**

The pyramids at Giza near Cairo, Egypt, were built over 4,000 years ago. The Great Pyramid is the only surviving monument of the Seven Wonders of the Ancient World.



EGYPTIAN GODS AND GODDESSES

- **Many gods and goddesses:** The ancient Egyptians believed that each of their deities had a particular role to play in keeping Egypt successful.
- **A living god:** The first pharaohs were thought to be a living version of the god Horus—a hawk-headed god of the sky that protected the pharaohs.
- **Mural paintings:** Images of the deities meeting a pharaoh in the afterlife were painted on the walls of the pharaohs' tombs.



Anubis | Isis | Osiris

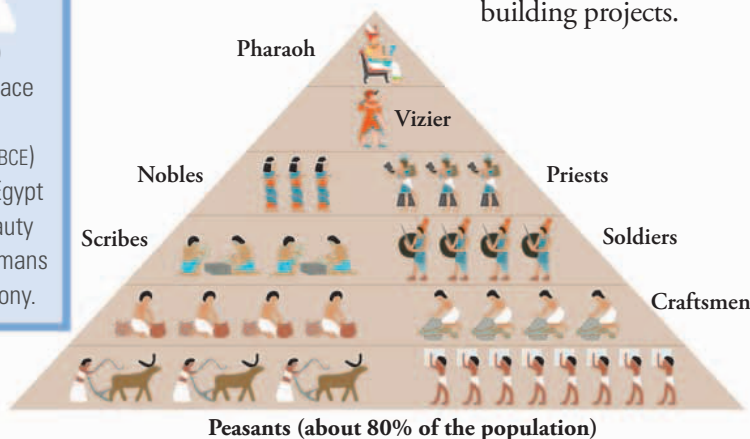
▼ **GOLDEN MASK**  
*The preserved body, or mummy, of Tutankhamun was discovered with a magnificent golden face mask on its head.*



WHO'S WHO?

- **Hatshepsut:** (reign 1473-58 BCE) This successful queen assumed the role of a pharaoh in place of her young stepson.
- **Tutankhamun:** (reign 1333- 23 BCE) This boy pharaoh's splendid tomb was discovered in 1922.
- **Rameses II:** (reign 1279-13 BCE) His long reign was a period of peace and prosperity in Egypt.
- **Cleopatra VII:** (reign 51-30 BCE) This last pharaoh of ancient Egypt was known for her great beauty and love affairs with the Romans Julius Caesar and Mark Antony.

**Egyptian social pyramid** The pharaoh at the top controlled all land, people, and possessions, and the vizier, his most trusted adviser, oversaw all the pharaoh's plans. The peasants at the bottom worked in the fields, producing the crops collected as taxes to feed everyone, but during the flood season joined the craftsmen, working on building projects.



TAKE A LOOK: ANCIENT EGYPTIAN ARTIFACTS

Historians have been able to discover much about the lives of ancient Egyptians from the markings, possessions, and records found.



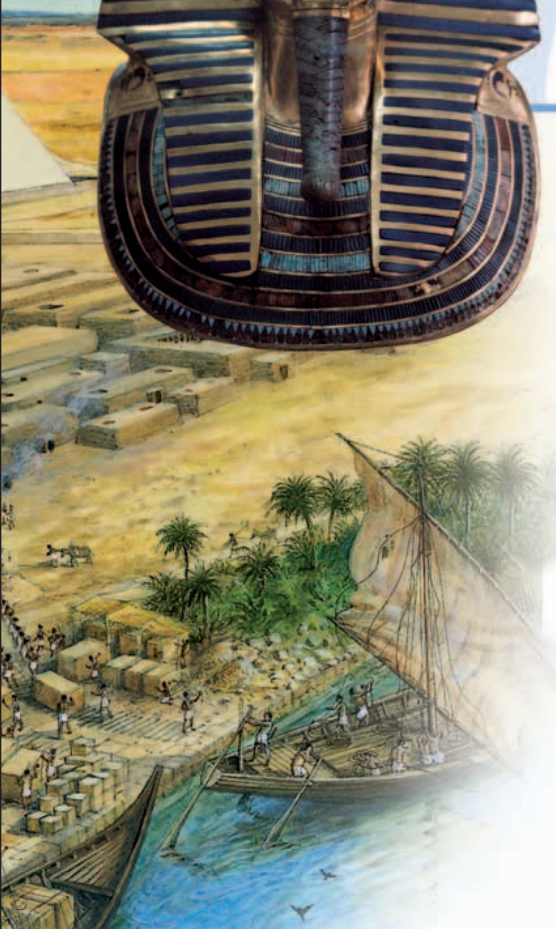
▲ **ANKH** Hieroglyphic symbol meaning "life" often shown being held by gods and pharaohs.



▲ **SCARAB DUNG BEETLE** Sacred symbol meaning "rebirth," relating to the god Khepri, who pushed the Sun across the sky.



▲ **PAPYRUS** The inner pith of this tall plant that grew along the Nile was used to make paper.







# Greeks and...

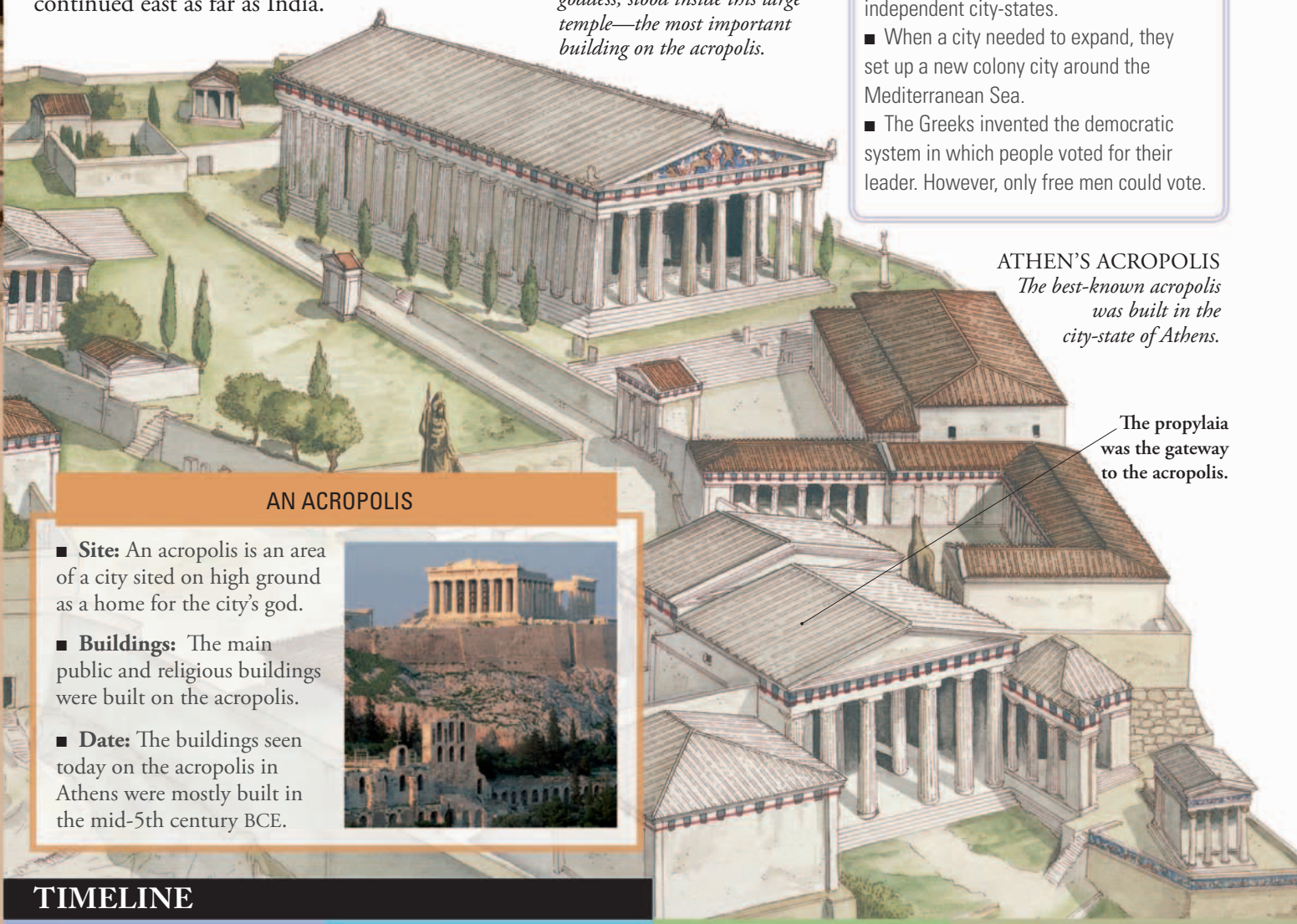
The ancient Greeks had one of the most advanced ancient civilizations. Historians know much about them from their writings, artifacts, and the influence of their culture on other nations.

**Alexander the Great's empire**  
 King Alexander III (356-323 BCE), who ruled over the Greek city-states from 336 BCE, led a 12-year-long military campaign, enlarging the ancient Greek Empire. He conquered the Persian Empire, Syria, and Egypt, and continued east as far as India.

▼ **PARTHENON** *A huge statue of Athena, the city's goddess, stood inside this large temple—the most important building on the acropolis.*

**GREEK POLITICS**

- The Greeks formed a collection of independent city-states.
- When a city needed to expand, they set up a new colony city around the Mediterranean Sea.
- The Greeks invented the democratic system in which people voted for their leader. However, only free men could vote.



**ATHEN'S ACROPOLIS**  
*The best-known acropolis was built in the city-state of Athens.*

## AN ACROPOLIS

- **Site:** An acropolis is an area of a city sited on high ground as a home for the city's god.
- **Buildings:** The main public and religious buildings were built on the acropolis.
- **Date:** The buildings seen today on the acropolis in Athens were mostly built in the mid-5th century BCE.



## TIMELINE

**1250 BCE**

The early Greeks and the people of Troy fought a legendary ten-year war.

190

**492–449 BCE**

After a 50-year war, the Greek city-states succeeded in defeating an invading Persian army.

**431–404 BCE**

The Peloponnesian War between the rival city-states of Athens and Sparta and their allies involved almost all the Greek world.

**334–323 BCE**

Alexander the Great expanded the Greek Empire across Persia.



# Romans

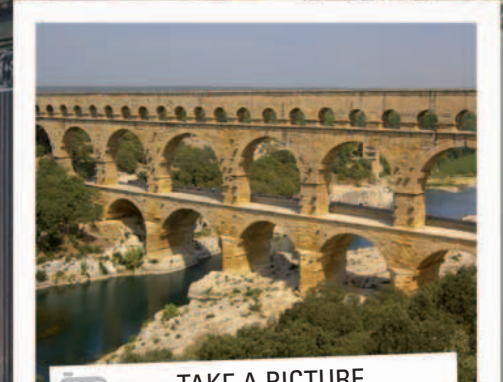
Starting out as a people from a small town ruled by a king in 753 BCE, the ambitious Romans ended up conquering a vast empire by impressive military power.

**The Roman Empire** By 117 CE, the Roman Empire stretched around the Mediterranean Sea, up through western Europe to Britain and across into Asia. In the 3rd century, the empire was divided between two emperors for better control.

HISTORY AND POLITICS

▼ THE ROMAN FORUM

*At the center of every Roman city was an open space surrounded by the main temples and public buildings. People gathered here to do business.*



TELL ME MORE...

The Roman Republic, formed in 509 BCE, was governed by a senate, but senators came from wealthy families and only Roman citizens could vote. Later, the empire was ruled by unelected emperors.

TAKE A PICTURE

Aqueducts, such as the Pont du Gard in France, are just one example of the Romans' great engineering feats across their empire.

148 BCE

At the end of the fourth Macedonian War, the Roman Republic finally defeated the ancient Greeks.



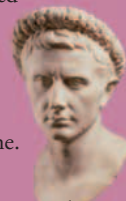
58–50 BCE

Julius Caesar, the military leader of the Roman Republic, conquered Gaul in western Europe.



27 BCE

Augustus changed the Roman Republic to an empire and became the first emperor of Rome.



476 CE

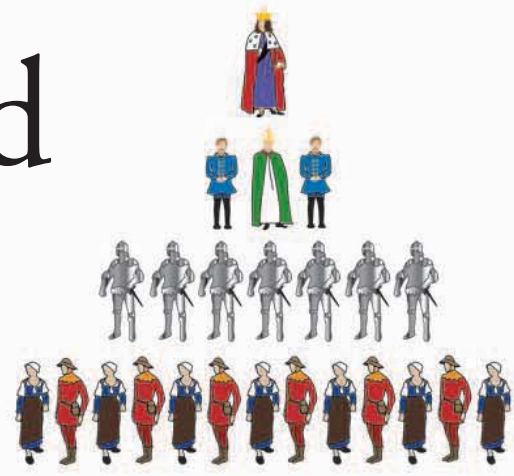
Attacks from barbarians caused the Western Roman Empire to collapse.






# Medieval period

The word “medieval” means “the middle ages,” and covers a period of more than a thousand years between the fall of the Roman Empire (5th century) to the Renaissance (16th century). During this time, Europe was all about who owned land—and so held the power.



**The feudal system** In many parts of Europe, society was organized into a class system, with the king at the top, who owned all the land. Barons and bishops were below him, then the lesser lords (knights), and, finally, the peasants.



 **TAKE A PICTURE**

On Christmas Day, 800 CE, Charlemagne (742–814) was crowned Holy Roman Emperor by Pope Leo III. Charlemagne was an important leader, establishing central government and schools in monasteries, spreading Christianity, and paving the way for modern Europe.



▲ **BUILT FOR DEFENSE** *In an age when land meant power, it was important to protect what you had. Cities, based around the lord's castle, were fortified with walls and a moat.*

- 1** *Raising the bridge and closing the **gates** slowed down invaders.*
- 2** *No large city was complete without a **cathedral**.*
- 3** *A lord could see enemy advances from his hill-top **castle** towers.*





◀ **CRESTS** Each guild had a coat of arms. This one belongs to the Merchant Adventurers of the City of York. These cloth traders funded ships for importing and exporting goods worldwide.

**Power in numbers** It wasn't just the noblemen who had power and influence. Craftsmen formed guilds to protect their businesses, making sure they had high wages and no competition. The guilds built grand halls (such as the London Guildhall, left) and influenced the day-to-day life of a city. But guild masters often used the guilds to increase their own wealth, rather than look after their members.

**Fighting for control** Europe in the Middle Ages looked different from today. For example, modern-day Spain was divided into four separate kingdoms, and parts of France came under the rule of different kings and princes—including the English crown. Wars were not uncommon, since kings sent (and often accompanied) armies into battle to take control of new land. The longest war was between England and France.



▶ **THE HUNDRED YEARS' WAR**

This series of battles between England and France actually lasted 116 years, from 1337 to 1453.

**TAKE A LOOK: TIMES OF CHANGE**

While warfare shaped the physical boundaries of countries during the Middle Ages, there were many other events that changed Europe at that time.



▲ **WEAPONS OF WAR**  
Kings often fought alongside their knights in major battles over control of land.



▲ **BLACK DEATH**  
In the 1340s, the Great Plague killed one-third of the population of Europe.



▲ **THE NEW WORLD**  
Explorers like Marco Polo and Christopher Columbus opened world trade routes.

**THE REFORMATION**

**THE CATHOLIC CHURCH**

- During the Middle Ages, the Catholic Church, with the pope at its head, was very powerful throughout Europe.
- But not everybody was happy with the Church's power and influence. The opponents called themselves Protestants.
- In 1517, German monk Martin Luther spoke out about corruption of Church officials. Ulrich Zwingli in Switzerland and John Calvin in France proposed similar ideas for reforming the Church.
- New, Protestant churches were set up in northern Europe, ending the total power of the Catholics in Europe.



# China's dynasties

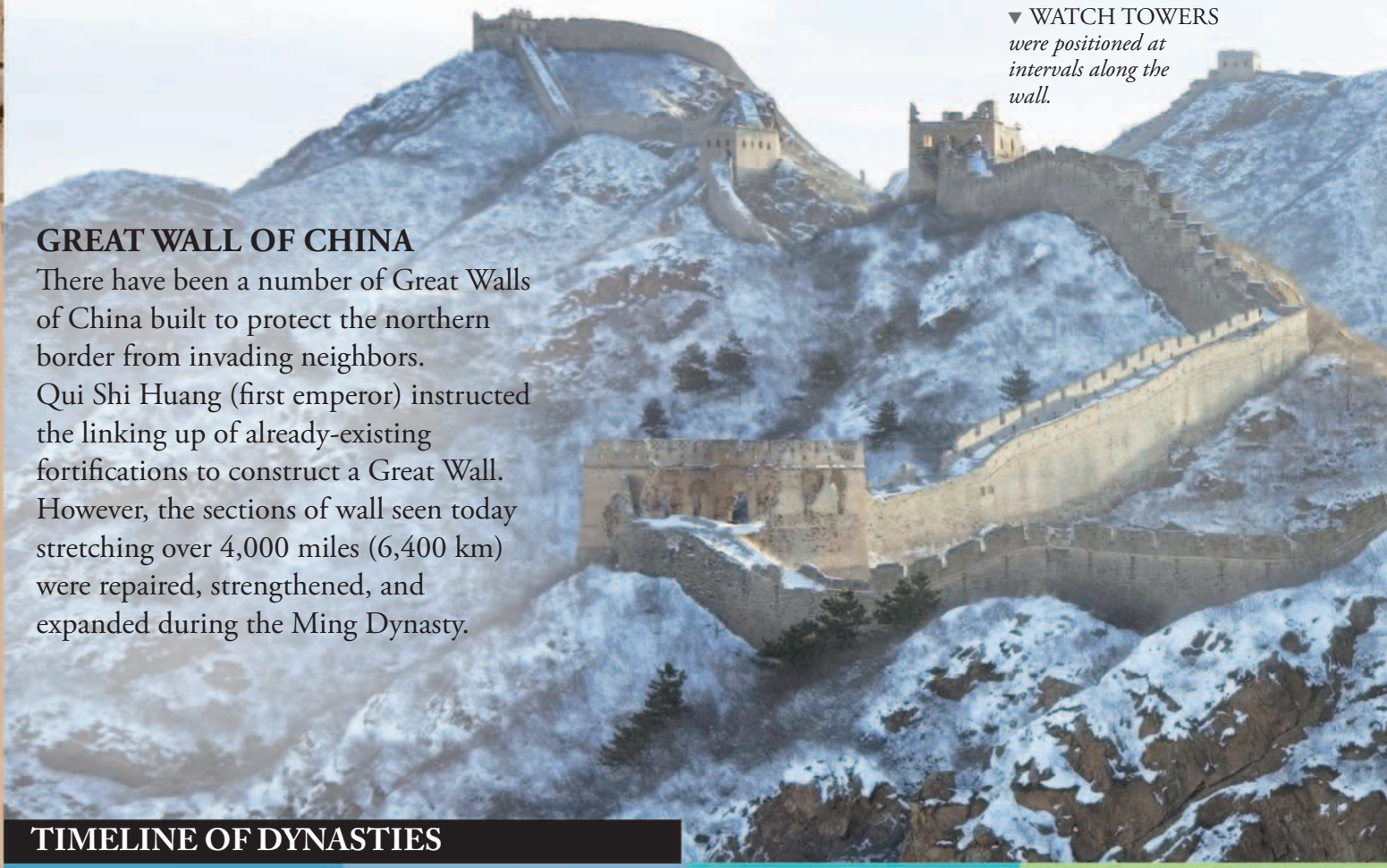


CHINA in 221 BCE united by the first emperor Qin Shi Huang.

China can claim to have the oldest continuous known civilization, which has lasted at least 4,000 years. Since the first city-states along the Yellow River, China has expanded (and at times contracted) under the control of a succession of ruling monarchs until 1912. Periods of unity and disunity have shaped the country's politics and history.

**WHO'S WHO?**

- **Confucius** (551-479 BCE) Famous Chinese philosopher whose teachings have influenced China's society.
- **Qin Shi Huang** (ruled 221-210 BCE) Proclaimed himself first emperor of China after uniting the warring states.
- **Wu Zhao** (ruled 690-705) Only woman to rule as emperor and probably murdered many people to rise to power.
- **Hongwu Emperor** (ruled 1368-1398) Founder of the Ming dynasty after defeating the Mongols.
- **Pu Yi** (ruled 1908-1912) Last emperor of China, abdicated aged six years old.


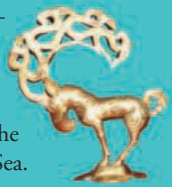
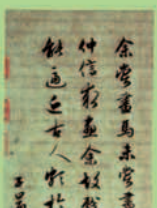


▼ WATCH TOWERS were positioned at intervals along the wall.

## GREAT WALL OF CHINA

There have been a number of Great Walls of China built to protect the northern border from invading neighbors. Qui Shi Huang (first emperor) instructed the linking up of already-existing fortifications to construct a Great Wall. However, the sections of wall seen today stretching over 4,000 miles (6,400 km) were repaired, strengthened, and expanded during the Ming Dynasty.

## TIMELINE OF DYNASTIES

DYNASTIES	221–206 BCE QIN	206 BCE–220 CE HAN	265–420 JIN
<p>Much of Chinese history can be split into time periods of the dynasties, or royal families. Each dynasty brought its own changes to the country.</p>	<p>A short-lived dynasty during which the traditional beliefs of Confucius were forbidden and his books burned.</p> 	<p>The Silk Road—an important trading route—was established from China to the Mediterranean Sea.</p> 	<p>Paper and ink became more popular and calligraphers perfected their writing style.</p> 



# 中国

**Forbidden City** In 1420, the Ming emperor and his household moved to a vast imperial palace in the capital, Beijing. Court officials and members of the imperial family were allowed inside, but only the emperor had unlimited access to all of the buildings.

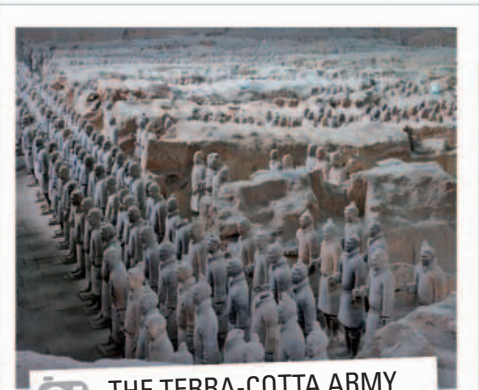
▼ 980 BUILDINGS survive enclosed by a 26 ft (7.9 m) high city wall.



**Middle kingdom** Zhōngguó (pronounced jung-gwo) meaning “Middle Kingdom,” was first used by the rulers of the ancient Zhou dynasty (1050-771 BCE), who believed their country was the “center of civilization.” Throughout China’s history, the name has had different meanings and caused conflict between dynasties. Only since 1911 has Zhōngguó officially been used for the country’s name.



▲ **COSTLY PROJECT** Millions of soldiers, prisoners, and local people were enlisted to build the Great Wall and many thousands died during the construction.



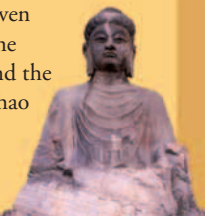
THE TERRA-COTTA ARMY

To prepare for his death, Qin Shi Huang (first emperor) ordered that thousands of life-size clay warriors, horses, and chariots were to be made to guard his tomb and help him rule his empire in his afterlife (👁️ p.165).



**618–907 TANG**

Women were given many of the same rights as men and the educated Wu Zhao became China’s only empress.



**1271–1368 YUAN**

Gunpowder, invented earlier by the Chinese, was developed to be used in powerful explosive cannons.



**1368–1644 MING**

Production increased of the very popular blue-and-white porcelain with painted scenes.



**1644–1912 QING**

Court officials wore robes with a dragon motif within the universe, symbolizing the emperor as the “Son of Heaven.”





# Islamic golden age

In the 7th century, Muhammad established the Islamic state in the Arabian Peninsula. In the centuries after his death, the Islamic empire expanded rapidly, spreading the faith and laws of Islam based on his teachings.

TELL ME MORE...

In 661, the Muslims divided over who to choose as the next religious leader. The Shiites accepted the descendants of Ali (Muhammad's son-in-law), known as Imams, while the Sunnites chose the descendants of the Umayyads, titled Caliphs.

## MECCA

Muhammad was born in Mecca (now in Saudi Arabia). After being forced out of the city due to his teachings, he returned eight years later with his army to take control and establish the city as the center of the faith of Islam.



◀ **PROPHET OF ISLAM** *At the age of 40, Muhammad had the first of many revelations about the word of God. His teachings were to become intertwined with the politics and social aspects of an Islamic state. His name is shown here in stylized form.*



### TAKE A LOOK: ISLAMIC ARTIFACTS

The Islamic civilization had a distinctive style in art, crafts, and architecture, and

made great advances in mathematics, astronomy, and medicines.



▲ **ISLAMIC ART**  
*Calligraphy and mosaics of glazed tiles were used to decorate buildings.*



▲ **ASTROLABE** *They perfected this instrument for calculating a person's position by using the Sun and stars.*



▲ **OTTOMAN VASE**  
*Flowers and large leaves were widely used as decorative patterns.*

## TIMELINE OF ISLAMIC EMPIRE

### 622–632 MUHAMMAD

Muhammad took control of Mecca and established the Islamic civilization.



### 661–750 UMAYYAD

The caliphs of the Umayyad family expanded the Islamic Empire (shown in green).



### 750–1258 ABBASID

Baghdad was made the Islamic capital and the city became the world's center of trade, learning, and culture.



Silver and copper basin



WHO'S WHO?

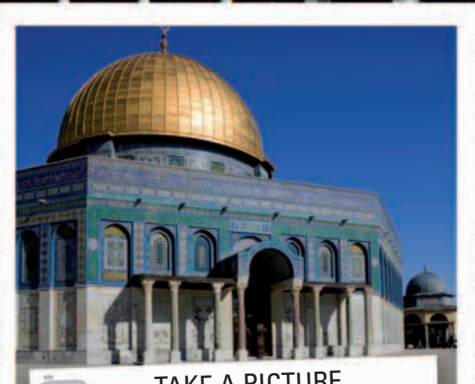
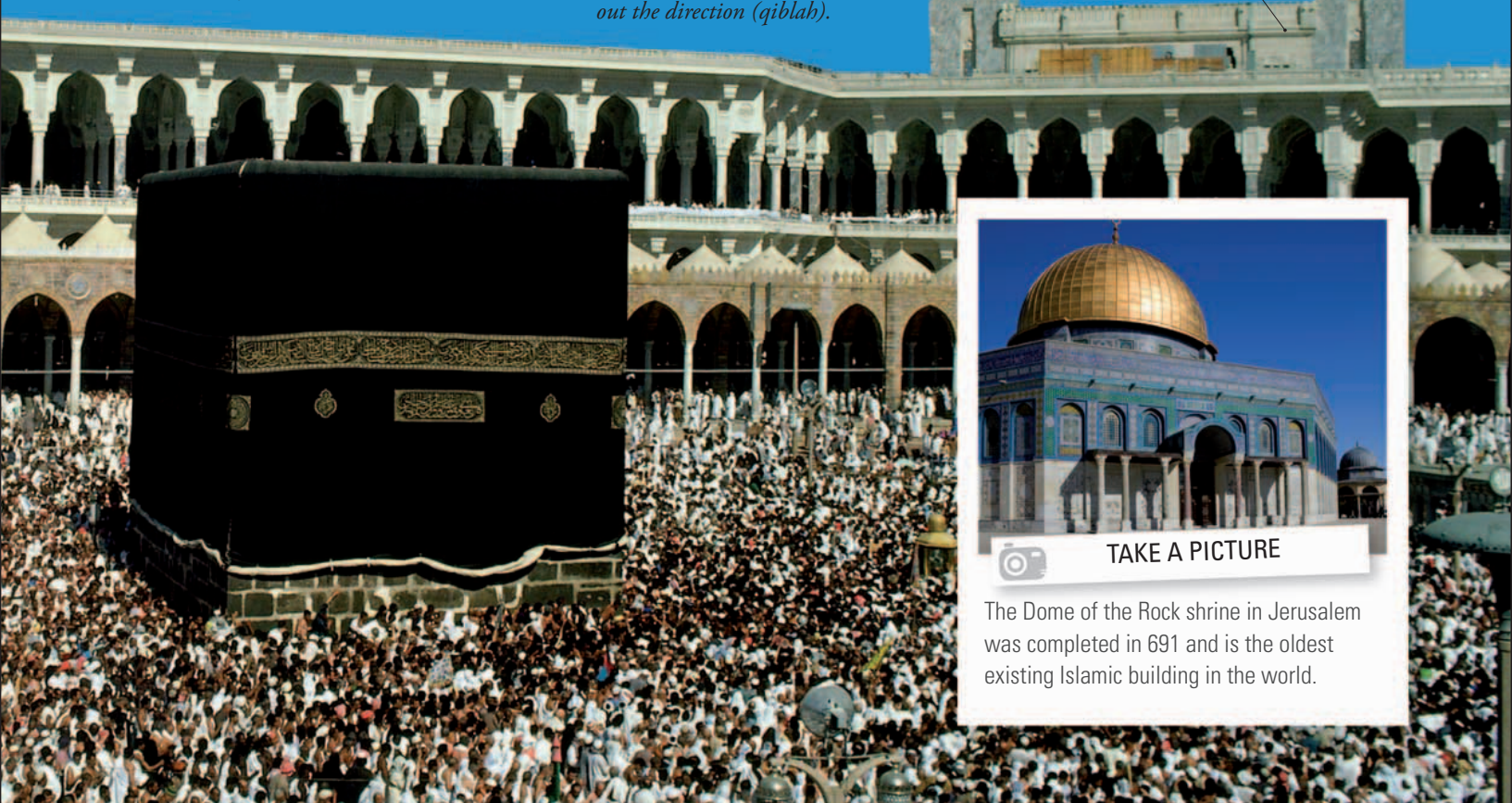
- **Muhammad** (570-632) He was the founder of the Islamic religion and the first Muslim political leader.
- **Ali ibn Abi** (599-661) He was the son-in-law of Muhammad and became the first Imam in 656.
- **Harun al-Rashid** (766-809) The fifth Abbasid caliph, who was the subject of the stories *The Thousand and One Nights*, also called *The Arabian Nights*.
- **Saladin** (1137-1193) A Muslim sultan (governor) of Egypt, Syria, Yemen, and Palestine, who captured Jerusalem and defeated the crusaders in 1187.

▼ **KAABA** According to Islamic tradition, this cube-shaped building in Mecca is said to be the house of God. Muslims (followers of Islam) are expected to visit it at least once in their lifetimes.

▲ **QIBLAH** Muhammad instructed Muslims to pray five times a day, facing the direction, or qiblah, of the Kaaba in Mecca. This instrument was used to figure out the direction (qiblah).

Minarets are the highest points in the mosque. Traditionally, a muezzin calls everyone to prayer from the minaret.

The Grand Mosque in Mecca

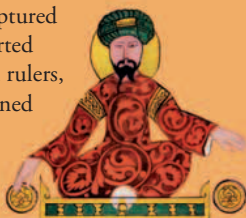


TAKE A PICTURE

The Dome of the Rock shrine in Jerusalem was completed in 691 and is the oldest existing Islamic building in the world.

1258 RISE OF THE SULTANS

Mongol invaders captured Baghdad and converted to Islam, while local rulers, called sultans, governed Egypt, Syria, and Palestine.



1369–1506 TIMURID

Timur, a Turkic-Mongol warrior, conquered the Islamic lands and one of his descendants founded the Mughal Empire in northern India.



1516–1924 OTTOMAN

The Ottoman Turks ruled over the Islamic state and expanded their empire into eastern Europe (shown in green).





# Aztecs

At the end of the 1100s, a tribe of hunters and gatherers from northern Mexico migrated south and, during the 1200s, settled as farmers on the islands of Lake Texcoco in the Valley of central Mexico.



**Map of empires**  
At the height of their empires, the Aztecs ruled over about six million people in central and southern Mexico and the Incas ruled over 12 million people living along the Pacific coast and in the Andes Mountains.



## Tenochtitlán

Around 1325, the Aztecs began building their vast capital city, Tenochtitlán, in the center of Lake Texcoco. Several highways linked the island-city to the mainland. In the center was a complex of religious buildings surrounded by palaces, warrior schools, and a ball court for playing a game called ulama.



The Great Temple

## 1300s

**CULTURES ESTABLISHED**  
*The Aztec and Inca tribes create settlements and increase in population.*

# Incas

A tribe of farmers led by their king, Manco Cápac, settled in Cuzco in the highlands of Peru during the 1100s. Like the Aztecs, they were later to form a strong and powerful warrior-nation.

### FAST FACTS

- Inca kings were called capac.
- The Inca language was quechua and the Aztec language was nahuatl.
- Both civilizations worshiped many gods and performed human sacrifices.
- The Incas traded with goods and services and the Aztecs traded with cacao beans and goods.



▲ MANCO CAPAC  
*First ruler of the Incas*



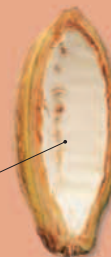
Knotted strings

Gold statue



▲ **GOLD** Many precious metals, such as gold, were found in South America and metalworking was a popular craft.

▲ **QUIPU** The Incas used ropes with different-sized knots to record information about their expanding empire.



Pod

Beans

◀ **CACAO** A bitter-tasting chocolate drink was made using the beans of the cacao plant.





▲ MASK OF A GOD  
*Mosaic made from turquoise gems*

Montezuma I



WHO'S WHO?

- **Acamapichtli** (reign 1376-96) A member of the ruling family of a neighboring state who became the first king of the Aztecs.
- **Montezuma I** (reign 1440-69) This ambitious king greatly expanded the Aztec Empire through trade and conquest.
- **Montezuma II** (reign 1502-20) The Aztec Empire reached its largest size during his reign and then the Spanish conquest began.
- **Hernán Cortés** (1485-1547) Spanish adventurer who overthrew the Aztec Empire in 1521 and claimed Mexico as land belonging to the Spanish crown.



▲ SACRIFICIAL KNIFE  
*Aztec priests cut out the still-beating hearts from prisoners as a sacrifice to their gods.*

**Empire building** The Aztecs became rich and powerful because they were extremely successful at growing crops. They became a nation of feared warriors since their large, conquering army could be fed. Merchants could trade goods with distant lands, creating wealth for the Aztecs.

Cortés arrives



**Spanish conquest** Hernán Cortés was welcomed as an honored guest by Montezuma II to Tenochtitlán in 1519 as was the custom of the Aztecs. However, Cortés arrested the king and two years later destroyed the city and the Aztec Empire.

1400s

EMPIRES EXPANDED

*The Aztecs and Incas extend their control over other tribes and gain more land.*

1500s

CIVILIZATIONS CONQUERED

*The Aztec and Inca empires are destroyed by the arrival of Spanish adventurers.*



◀ MACHU PICCHU  
*Mountain city built by Capac Yupanqui.*

**Inca conquests** Capac Yupanqui (reign 1438-71) began the expansion of the Inca Empire. A vast network of roads were built to link their territory.



▶ LLAMAS were valued for their wool, their meat, and for carrying goods along the roads.

Francisco Pizarro

In search of gold and other precious metals in South America, the Spanish adventurer Pizarro met the Incas. In 1533, he took control of Cuzco and claimed the land for Spain.

TELL ME MORE...

Despite having only a small army, Pizarro was able to seize the Inca ruler Atahualpa after he refused to accept Christianity and the rule of Spain on November 16, 1532.

Pizarro meets Atahualpa





# Colonial America

By the early 1600s, more and more Europeans were sailing across the Atlantic Ocean to establish colonies in the eastern areas of North America. Over the next 170 years these colonies grew.



► **POCAHONTAS**  
As a young girl, Pocahontas helped to make peace between the Jamestown settlers and her Native-American tribe.

**TELL ME MORE...**

In November, 1620, a group of Pilgrims from England on board the *Mayflower* arrived in North America after a grueling 66-day journey. They founded Plymouth in Massachusetts.

Reconstruction of the *Mayflower*



**The Plymouth settlers**

The *Mayflower* pilgrims had come to the “New World” so they could worship freely without persecution. Their new life was tough and half of the group died from disease or starvation during the first winter. However, most of the local Native Americans were welcoming and showed them suitable crops to grow.



The Thanksgiving festival now celebrated in November in the United States has its origins in the first Thanksgiving feast held in the fall of 1621 by the Pilgrims and Native Americans to celebrate their first good harvest.

**TIMELINE OF COLONIAL AMERICA**

1607

The Jamestown settlement in Virginia was the first permanent English settlement in North America.



1608

Quebec City is founded by the French along the Saint Lawrence River.

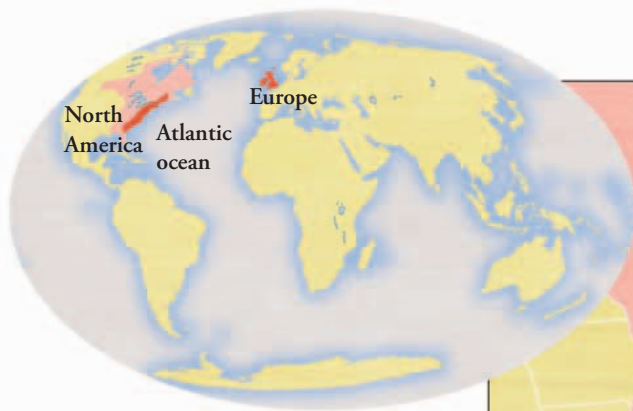


1620

The *Mayflower* pilgrims establish a settlement at Plymouth, Massachusetts.







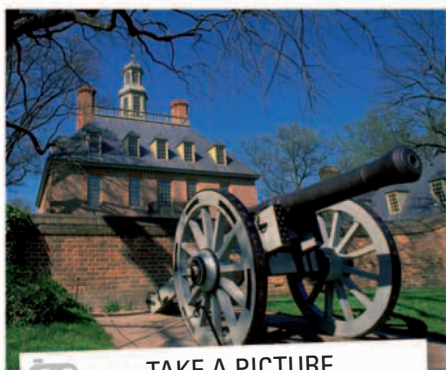
**The British colonies** By 1733, there were 13 colonies loyal to Britain along the east coast of North America. In 1763, the French surrendered their land to the British. In the 1760s, Britain began to tax the American colonists, but their authority over the New World was starting to weaken, since the colonists no longer needed their protection.



COLONIAL AMERICA

- The original 13 colonies
- Other British territories

- MS** Massachusetts
- NH** New Hampshire
- RI** Rhode Island
- CN** Connecticut
- NY** New York
- NJ** New Jersey
- PA** Pennsylvania
- MD** Maryland
- DEL** Delaware
- VA** Virginia
- NC** North Carolina
- SC** South Carolina
- GA** Georgia



TAKE A PICTURE

The historic area of Williamsburg, which became Virginia's capital in 1698, has been restored and re-creates colonial times.

► **DECLARATION** On July 4, 1776, the Continental Congress of the American colonies issued a Declaration of Independence, signed by representatives of all 13 colonies. The united colonies were free, independent states.



**Revolutionary War** In the 1770s, the American colonists began to rebel against British rule and were especially angered by the heavy tax on tea in 1773. Between 1775 and 1783, the colonists fought the British army and won. The British were forced to recognize their new independent country—the United States of America.

1663

Companies were established to trade goods, such as fur skins and tobacco, with Europe.



1763

The French surrendered their colonies to Britain, expanding the area the British controlled.



1773

The Boston Tea Party was a protest by some American colonists angered by their high taxes paid to the British.



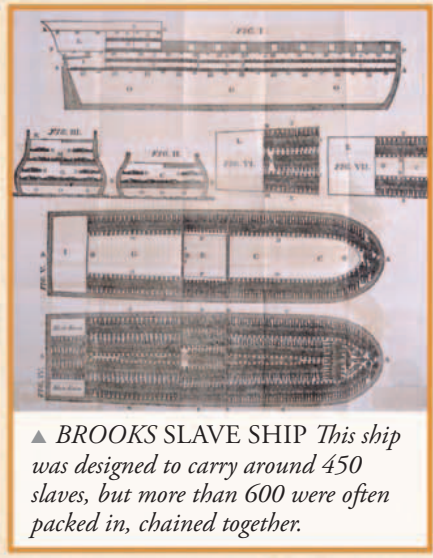
1775–1783

The Revolutionary War was when the 13 colonies rebelled against the British and won independence.





# The slave trade



▲ **BROOKS SLAVE SHIP** This ship was designed to carry around 450 slaves, but more than 600 were often packed in, chained together.

Slavery has been a feature of many societies, such as ancient Egypt and Rome. But it was the Atlantic slave trade that made slavery a worldwide issue. It had its roots in the Portuguese transportation of workers from Africa to Madeira, in 1470. By the time slavery was abolished 400 years later, around 12 million slaves had been taken from Africa to the New World.



## THE TRIANGULAR TRADE

The slave trade was all about money. European traders exported goods to Africa, then used the ships to pick up a new cargo: people. They were taken to work on plantations in southern North America, South America, and Caribbean islands.

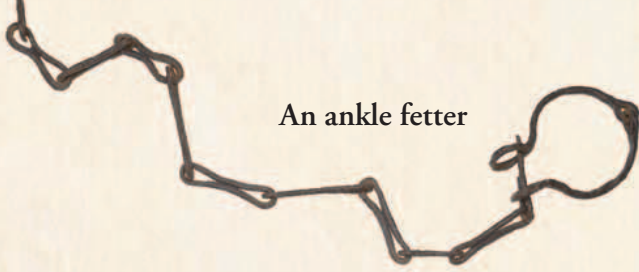
**1 EUROPE TO AFRICA** The Europeans traded copper, iron, cloth, wine, glassware, and guns with African landlords for people.

**2 AFRICA TO AMERICAS** Called "The Middle Passage," people were snatched from villages and fields and marched to the coast to slave ships.

**3 AMERICAS TO EUROPE** Sugar, rice, cotton, coffee, tobacco, and rum from the plantations were brought back to Europe.



An ankle fetter



## SLAVES FOR SALE

On arrival in the New World, slaves were taken to markets, where they were sold by auction to plantation owners. The slaves were branded—burned with hot irons—with the mark of their new owner. Men, women, boys, and girls were all put up for sale.



▲ **NO ESCAPE** *From the moment they were first seized in Africa, slaves were forced to wear shackles such as neck collars and ankle fetters. They were chained together so that they could not escape.*



◀ **IN THE FIELDS** *Slaves were made to pick crops such as cotton.*

**Forced labor** Slaves were taken to work on the plantations set up by European settlers. Life was brutal, with long hours, poor food rations, no wages, and frequent beatings. Children born to slaves became slaves themselves and belonged to the plantation owner, who could send them away from their families to work on another plantation.



▲ **“THE MOSES OF HER PEOPLE”** *Harriet Tubman was an escaped slave who led hundreds of other slaves to their freedom, at great risk to herself. She later became a leading abolitionist.*

## FROM SLAVERY TO CIVIL WAR



*Confederate general*

By the late 18th century, people were campaigning for the end of slavery.

■ **The Abolition of Slave Trade Act** was passed in Britain in 1807, outlawing the slave trade, but slavery itself didn't end in the British Empire until 1833, and in the United States until 1865.

■ Abolition was one of the main causes of the **Civil War** (1861–1865), since the Southern Confederate “slave states” did not want to end slavery—but the Northern Union states did.

■ **Abraham Lincoln** was one of the key antislavery figures in the United States. In 1863, he signed the Emancipation Proclamation, bringing an end to slavery.

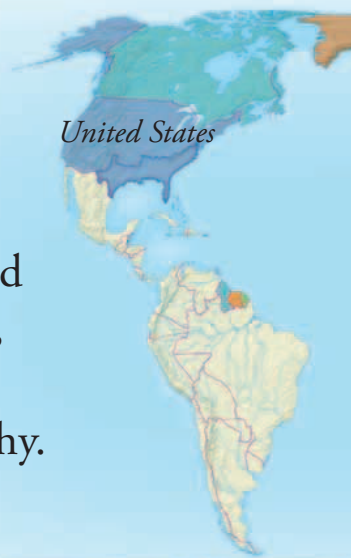


*Union soldier*



# The age of empire

Since the 1600s, European countries had steadily gained land and influence over countries around the world. From the mid-1800s, they competed against each other to control new trade markets, increasing the size of their empires and becoming wealthy.



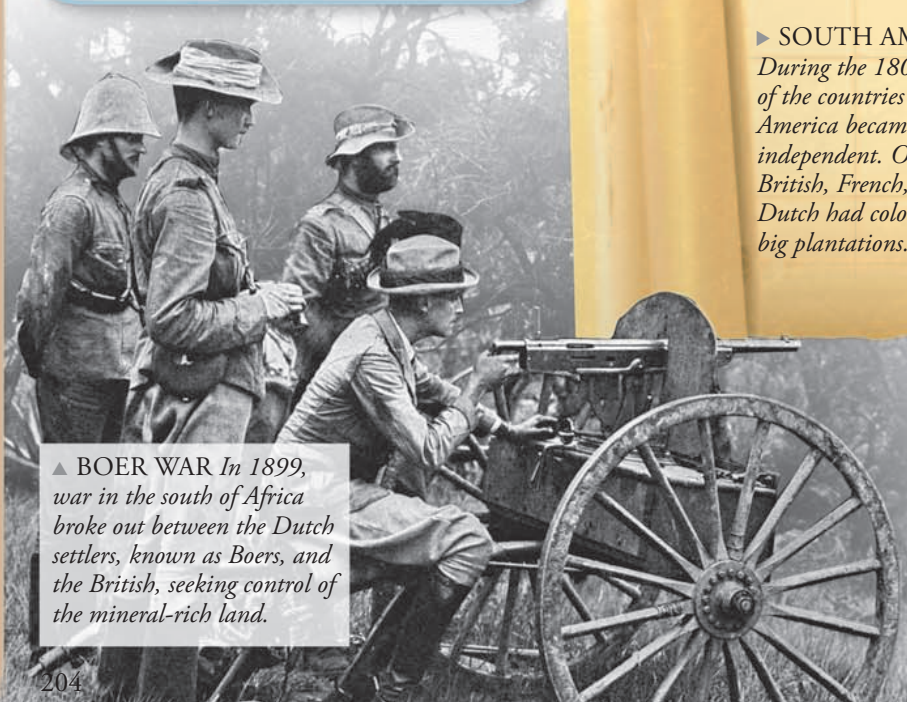
**North America**  
 Many people from Europe immigrated to the United States or Canada to escape bad conditions at home, such as the potato famine in Ireland. The arrival of these new settlers led to the exploration of remote inland areas and a route across the whole continent.

**TELL ME MORE...**

In 1805, Meriwether Lewis and William Clark were the first American explorers to find a route through the Rocky Mountains to reach the western territories of America. Other explorers, traders, and settlers followed afterward.

## IMPORTS AND EXPORTS

European countries imported raw materials from their empires and exported manufactured goods back to their colonies.



**▲ BOER WAR** In 1899, war in the south of Africa broke out between the Dutch settlers, known as Boers, and the British, seeking control of the mineral-rich land.

**Africa**  
 The “scramble for Africa” began in the 1870s, when European countries competed against each other to gain control of land on this continent. Explorers had found raw materials such as gold and diamonds, and there was land and people available for setting up plantations.





*This map shows the borders and empires in 1900.*

### Empire-builders

The main European colonial powers were Great Britain, France, the Netherlands, and Portugal. By the end of the 19th century, Great Britain's empire covered one-quarter of Earth's land surface.

- Britain
- Italy
- France
- Netherlands
- Spain
- Germany
- Portugal
- Ottoman Empire

### TAKE A LOOK: TRADE

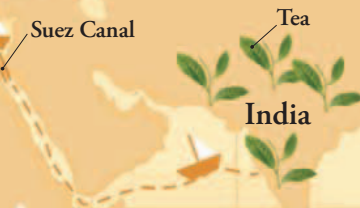
Access to raw materials was very important to the growing industrial countries. It was simpler and more profitable to own the country where these came from rather than negotiate with the local rulers. Colonies also provided cheap labor for the mines and the plantations.



Cotton Rubber

#### ▼ EGYPT

*The Suez Canal, opened in 1869, allowed an easier and quicker access route to India.*



#### ► MALAYSIA

*The British government set up very profitable tin mines and rubber plantations.*



Gold

Australia



Gold

#### ► INDONESIA

*After the success of the Dutch East India Trading Company in the 17<sup>th</sup> and 18<sup>th</sup> century, the Dutch government took control and set up big plantations to grow crops such as coffee and spices.*



#### ▲ AUSTRALIA

*The discovery of gold in the town of Victoria in the 1850s led to a gold rush. The European population grew very quickly.*

### Australia

The British used convicts to establish their first colonies in Australia. Free settlers began to arrive in 1793. The native Aborigines were pushed off their land by the new settlers and forced into the Outback—an inhospitable, unfertile area that the settlers did not want.

### INDEPENDENCE



The Commonwealth Games

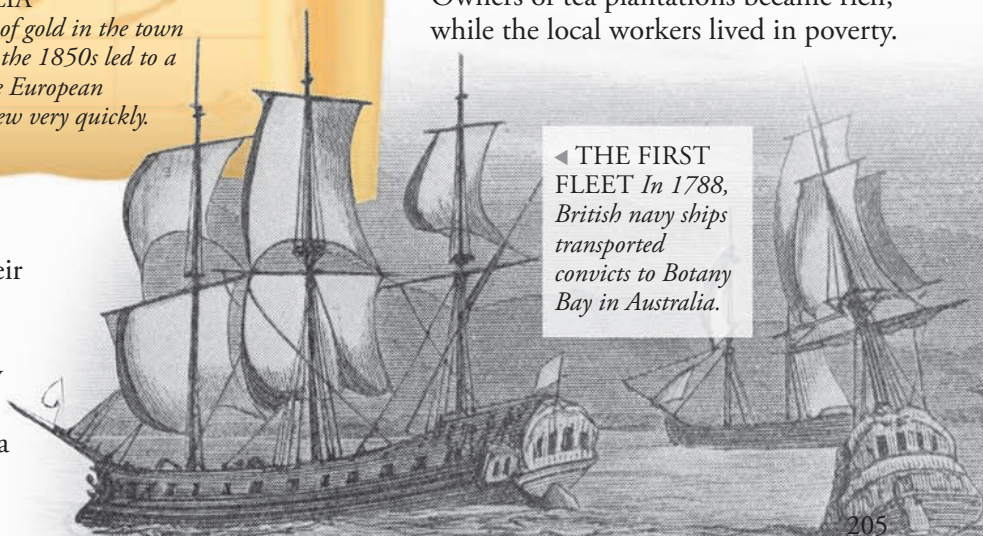
After World War II, many colonies started campaigning to become independent countries. During the 1940s through 1960s, most gained independence, although the transition for some countries, such as India, caused violence. Many nations still have links to their colonial power. The Commonwealth is an organization of 53 countries that were once part of the British Empire.



### India

By 1900, Britain ruled the whole of India. Many British administrators and traders lived there with their families, enjoying a privileged colonial lifestyle. Owners of tea plantations became rich, while the local workers lived in poverty.

◀ THE FIRST FLEET In 1788, British navy ships transported convicts to Botany Bay in Australia.





# Industrial Revolution

Between 1750 and 1850, the development of power-driven machines transformed the lives of people, first in Britain and then other European countries and the United States. This period is known as the Industrial Revolution.

*Burning the coal to produce steam to power the machines produced choking smoke.*



**Child labor** Children as young as six years old worked in the factories, until 1833, when under-nines were banned. They worked up to 12 to 14 hours a day with few breaks. Sometimes, they were injured or even killed by the machinery.

## WOW!

Before the Industrial Revolution, most people worked as farmers in the fields. Spinning and weaving were done at home. The invention of machines changed this. Thousands of workers seeking more pay moved into the towns to work in the newly built factories that housed these big machines.

▲ **FACTORIES** From the 1790s, steam power replaced the previously water-powered machines. Inside the factories, the noise of the machines was deafening. Outside, the towns were dirty and unhealthy places.

## TIMELINE OF INDUSTRIAL INVENTIONS

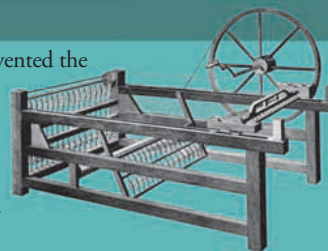
1712

**Thomas Newcomen** built the first commercially successful steam engine. It was used to pump water out of mines.



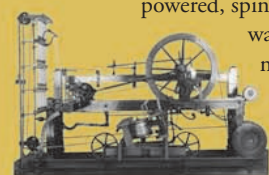
1764

**James Hargreaves** invented the spinning jenny—a mechanized spinning wheel that could spin eight threads at once.



1779

**Samuel Crompton's** water-powered, spinning “mule” was bought by many factory owners.





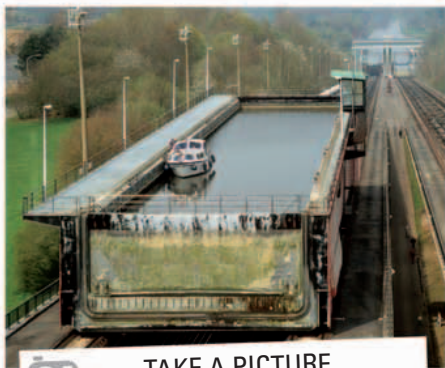
## TELL ME MORE...

The Industrial Revolution caused much unrest. Skilled textiles workers, in particular, were angered by the introduction of looms that could be worked by unskilled workers making low wages, forcing them out of work. One group, known as the Luddites, destroyed the machines in cotton and woolen mills.



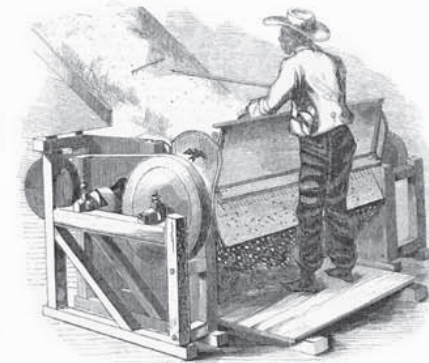
## WHO'S WHO?

- **James Watt** (1736-1819) A Scottish engineer who made improvements to the steam engine in 1769 so that machines could be powered without water.
- **Eli Whitney** (1765-1825) An American inventor who designed the cotton gin while staying on a plantation in the Southern states.
- **Francis Cabot Lowell** (1775-1817) An American merchant who established the first textile mill in the United States.
- **George Stephenson** (1781-1848) An English engineer who built the first public railroad line in the world.
- **Isambard Kingdom Brunel** (1806-1859) A British engineer who designed many tunnels, bridges, railroad lines, and ships.



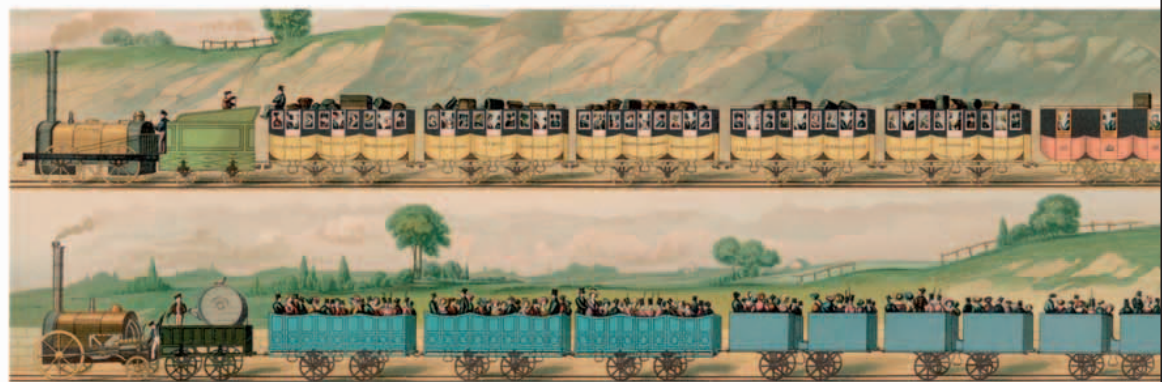
## TAKE A PICTURE

Canals were built to transport the heavy loads to and from the factories. The boat lifts on the Canal du Centre, Wallonia, in Belgium, show the amazing engineering feats of this age.



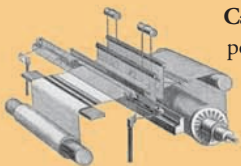
**Cotton gin** The US became the world's leading cotton producer, thanks to the invention of the cotton gin by Eli Whitney. This machine could quickly separate the cotton fibers from the seeds, which had previously taken ages to do by hand.

**Railroad mania** In 1804, Richard Trevithick added wheels to his steam engine so that it could run along tracks. Within thirty years, a network of railroads for transporting raw materials, goods, and people by steam locomotives was constructed. Traveling around was now much quicker.



1785

Textile-making could be done much faster by **Edmund Cartwright's** power loom.



1793

Cotton could be produced much faster with **Eli Whitney's** cotton gin.



1801

**Joseph-Marie Jacquard's** loom was the first machine to be controlled by punched cards—an idea later used in computing.



1830

The world's first all-steam passenger railroad opened in Britain.





# World War I

At the beginning of the 1900s, military and political tensions existed between some of the countries of Europe. The assassination of the heir to the throne of Austria-Hungary was the spark needed to fire up a war that involved the world.

## WHO'S WHO?

- Two main groups battled each other—the Allies led by the British, French, and Russian armies, and the Central Powers led by the German, Austro-Hungarian, and Turkish armies.
- The British and French armies included many recruits from their colonies and territories around the world.
- In total, nearly 30 countries were drawn in to take part in the fighting.
- The US joined the war in 1917.

## MILITARY TRANSPORTATION

- **Aircraft:** Biplanes and triplanes were used to fly over enemy lines to observe their movements and take photographs.
- **Vehicles:** Horse-drawn vehicles were gradually replaced by mechanical ones to transport men and supplies to and from the front line.
- **Tanks:** The first tanks used in 1916 were not very reliable, but a year later they were leading the way across to the enemy trenches, shielding the troops.
- **Warships:** Fleets of warships were used to protect supply ships from attacks by the German U-boats.



- Allied powers
- Central powers
- Neutral nations
- X Key battle sites

**World at war** Although most of the fighting took place in Europe, there was also fighting in the Middle East, in Africa, and in the German colonies in China and the Pacific Ocean.

## TIMELINE OF WORLD WAR I

1914

The assassination of Archduke Francis Ferdinand on June 28, 1914, caused Austria-Hungary to declare war on Serbia. European countries took sides, and by August The Great War had begun.



1915

The German's zeppelins made frequent nighttime bombing raids over British cities.





**THE FRONT LINE**

By the end of 1914, a network of trenches zigzagged from the Belgian coast to the Swiss border, forming the Western Front. From these positions, the Allied troops tried to push back the advancing German army, but neither side made much progress. Under fire from machine guns, the strip of land between each other's trenches was impossible to cross.

► **CROSSING NO-MAN'S LAND**  
*Most attempts to advance occurred at dawn or dusk.*

Trenchcoat

**Gas attack**

A deadly chlorine gas was used for the first time in the battle for the Belgium town of Ypres in 1915.

HISTORY AND POLITICS



**TAKE A PICTURE**

More than half of the 65 million men who fought in the war were killed or injured and about 6.6 million civilians also died.

**1916**

The naval battle of Jutland was the largest fought in history.



**1917**

The US joined the Allies, angered by the German U-boat attacks on shipping in the Atlantic Ocean.



**1918**

At 11 a.m. on the 11th day of the 11th month (November), an armistice (cease fire) took place. A peace treaty was later signed.





TELL ME MORE...

The Nazi party, led by Adolf Hitler, was voted into power in 1933. Hitler promised the German people an end to unemployment and hardship and wanted to restore the country's pride and military strength.

# World War II

The peace treaty signed at the end of World War I (the Treaty of Versailles in 1919) forced Germany to give up much of its land and wealth and restricted the size of its army. Twenty years later, the Nazi Party in Germany had rebuilt the nation, and their leader, Adolf Hitler, was determined to rule Europe.



Adolf Hitler

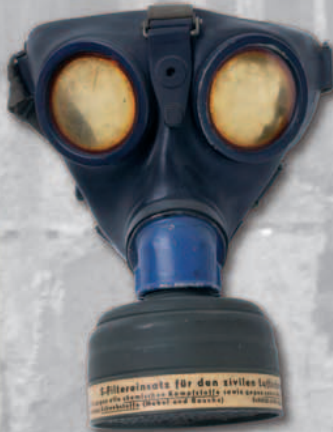
**Adolf Hitler** (1889-1945) Born in Austria, Hitler became an influential politician in Germany. After being appointed chancellor in 1933, Hitler created a one-party state and made himself an all-powerful dictator.

**Destruction** Bombing raids by the Allied and Axis powers caused huge destruction across Europe, the USSR, and east Asia. The raids were intended to target strategic buildings, such as airfields, factories, ports, and railroads, but often homes were destroyed, killing civilians or forcing them to evacuate (leave the area).



FAST FACTS

- The leaders of Britain (Winston Churchill), the Soviet Union (Josef Stalin), and the US (Franklin Roosevelt) met twice during the war to discuss strategies.
- Resistant groups of people from German-occupied countries helped the Allies by spying and acts of sabotage.



▲ **GAS MASK** Countries feared that gas would be used by the enemy so many people were issued with gas masks. They were never needed.

## TIMELINE OF WORLD WAR II

1939

On September 1, German forces invaded Poland. Britain and France declared war on Germany. 210



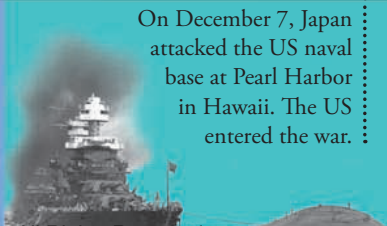
1940

Between June and October 1940, the German air force battled the British air force in the skies above Britain.



1941

On December 7, Japan attacked the US naval base at Pearl Harbor in Hawaii. The US entered the war.



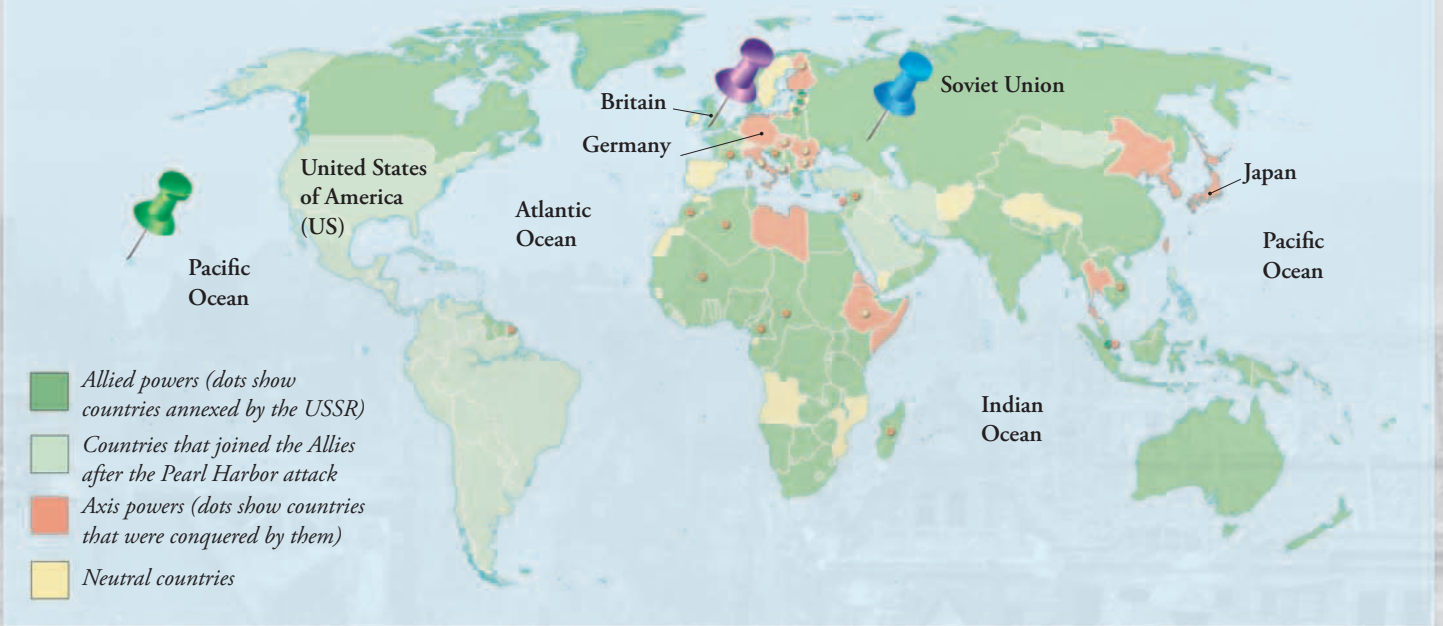
1942

In August, the Germans began the six-month-long battle for Stalingrad in the Soviet Union.





THE WORLD AT WAR



**World at war** Until mid-1941, the two sides were the Axis (Germany, Italy, and some east European countries) and the Allies (Britain, France, and countries in their empires). Nations around the world became involved when Germany invaded the Soviet Union and Japan's attacks began.

**BATTLE OF BRITAIN** After conquering France in June 1940, Germany planned to take over Britain. The British air force was targeted first, but the German air force was unable to defeat it.

**STALINGRAD** Germany invaded the Soviet Union in 1941. There was a huge loss of life on both sides, especially in the battle for Stalingrad in the south. In 1943, the weakened German army surrendered.

**PEARL HARBOR** The unexpected attack by the Japanese air force on the US naval base in Hawaii destroyed 19 ships and killed 2,403 soldiers. The United States immediately declared war on the Axis powers.

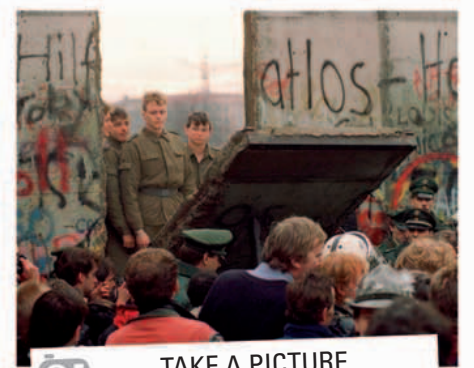


▼ **THE CAMPS** Auschwitz in Poland was one of eight concentration camps that had gas chambers.

**The Holocaust** The Nazi party was very anti-Semitic (against Jews). They forced Jews to wear badges with a yellow star and, from 1942, sent them to concentration camps. Many millions of Jews died from illness, starvation, and in gas chambers.



THE COLD WAR



TAKE A PICTURE

After the war, relations between the Soviet Union and the US became very tense. Eastern and western Europe were separated. The collapse of the Berlin Wall, Germany, in 1989 became a symbolic end to this Cold War.

1943

In May, the Axis army in North Africa finally surrendered to the Allies.



1944

On June 6 (D-day), Allied forces invaded the beaches of Normandy, France, and began to push back the Axis forces.



1945

In May, Germany surrendered, but the war continued in east Asia. Japan surrendered only after atomic bombs were dropped on two cities in August.





# Revolution!

World history has been marked by episodes when a sudden uprising of people driven by hardship has overthrown those in power. An alternative political system has been established in the hope for a better life.

## REVOLUTIONARY LEADERS

- **Vladimir Lenin** (1870-1924) was leader of the Bolshevik Social Democratic Workers' party and first head of the Soviet state.
- **Mohandas Gandhi** (1869-1958) is considered the father of India.
- **Mao Zedong** (1893-1976) was a Chinese communist leader and the founder of the People's Republic of China.
- **Fidel Castro** (1926- ) has been president of Cuba since 1949 and is the world's longest serving leader.

**The Year of Revolution** A wave of unrest spread across many European countries in 1848. With many starving and unemployed, the demonstrators wanted more rights and a greater say in how their countries were governed. Although the revolts fizzled out, they were the sparks for later political reforms.

▼ *In March, a peaceful demonstration in Vienna, Austria, turned violent.*

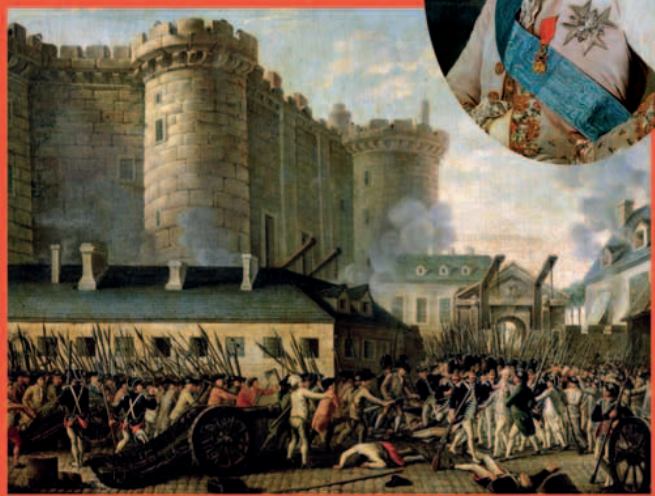


1789

**"LIBERTY, EQUALITY, FRATERNITY!"**  
*Despite France facing severe food and money shortages, King Louis XVI and his wife Queen Marie-Antoinette enjoyed a luxurious lifestyle.*

**The storming of the Bastille**  
 On July 14, 1789, the starving people of Paris rioted when they heard rumors that King Louis XVI had ordered the army to suppress the commoners and wanted to raise taxes.

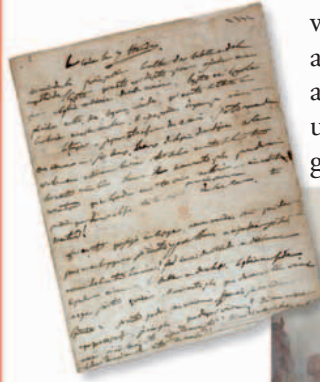
▼ **LOUIS XVI**  
*Executed in 1793*



1799

**"WORKERS OF ALL LANDS, UNITE!"**  
*In 1848, a German political writer, Karl Marx, published his thoughts on communism.*

▼ *Napoleon wrote about 33,000 letters.*



► **NAPOLEONIC WARS** *Napoleon crowned himself emperor of the First French Empire in 1804 and led successful military campaigns across Europe.*

1848

**The French Revolution**  
 After the death of Louis XVI, the country became a republic, but there was a reign of terror, with thousands of people executed at the guillotine. In 1799, the army eventually gained control under the dictatorship of its general, Napoleon Bonaparte.





**India's peaceful revolution** The political figure Mohandas Ghandi returned to India in 1914. He began a gradual campaign of urging Indians to boycott the British-run courts and schools and resign from government positions. In 1930, Ghandi led a 240 mile (386 km) march protesting against the tax on salt.

*The Indian spiritual and political leader, Mohandas Ghandi, in 1947—the year India finally won independence from the British.*



1914-47

“BE THE CHANGE YOU WANT TO SEE IN THE WORLD.”  
Ghandi encouraged resistance through non-violent civil disobedience.

1917

**Cuban revolution** The revolutionary Fidel Castro led a small band of rebels and peasants in their two-year fight against the large army of the dictator Fulgencio Batista. When Castro took power in January, 1959, he made many reforms, improving Cubans' healthcare and education.



*Che Guevara was one of Castro's rebel group leaders.*

Fidel Castro



1956-58

“SMASH THE OLD WORLD, ESTABLISH A NEW WORLD.”  
Young people in China formed the Red Guards to promote Mao's message.

1966-76



▲ Workers and mutinied soldiers marched on the streets of Petrograd (St. Petersburg).

**The two revolutions** Stirred up by the Bolshevik socialist party, the starving and war-weary Russians demonstrated against the unpopular Czar (king) Nicholas II in February, 1917, who then abdicated. In October, led by Vladimir Lenin, the Bolsheviks overthrew the government to form the first communist state.

▲ HAMMER AND SICKLE BADGE  
In 1922, Russia was renamed the Union of Soviet Socialist Republics (USSR). Their symbol represented the unity of the workers and peasants.

**China's cultural revolution** In 1966, the leader of the Chinese Communist Party, Mao Zedong, launched a campaign to make China a classless society. Millions of educated and privileged people were forced into manual labor to be “reeducated” and many thousands were killed.

▼ Everyone had to read and carry around a copy of Mao's “Little Red Book.”

Chairman Mao reimposed his control





# In the news

Every day, history is being made. Events affecting people's lives and altering the politics of nations around the world are reported in the newspapers, or on the television and the Internet.

▶▶▶ FAST FACTS ▶▶▶

- On September 11, 2001, terrorists linked with a group called Al-Qaeda attacked buildings in the United States. These 9/11 attacks have led to a "War on Terror" against Muslim militants.
- Founded in 1945, the United Nations is an international organization that seeks to achieve world peace.

## BREAKUP OF THE USSR

In 1991, the Union of Soviet Socialist Republics (USSR) was broken up and some areas became independent countries. Since then, other areas have wanted independence, sometimes causing unrest.

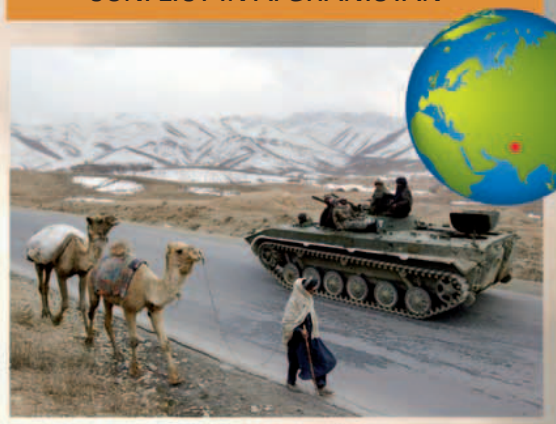


**PROTEST** *In 2008, people protested during the conflict between Russia and the independent state of Georgia.*

Russia, or the Russian Federation, became the largest of the new countries, continuing as a communist state. Rebel fighters from the Chechen Republic, or Chechnya, have taken hostages in an attempt to get independence from Russia. In 2008, Russia and Georgia were fighting over the control of the areas of Abkhazia and South Ossetia.

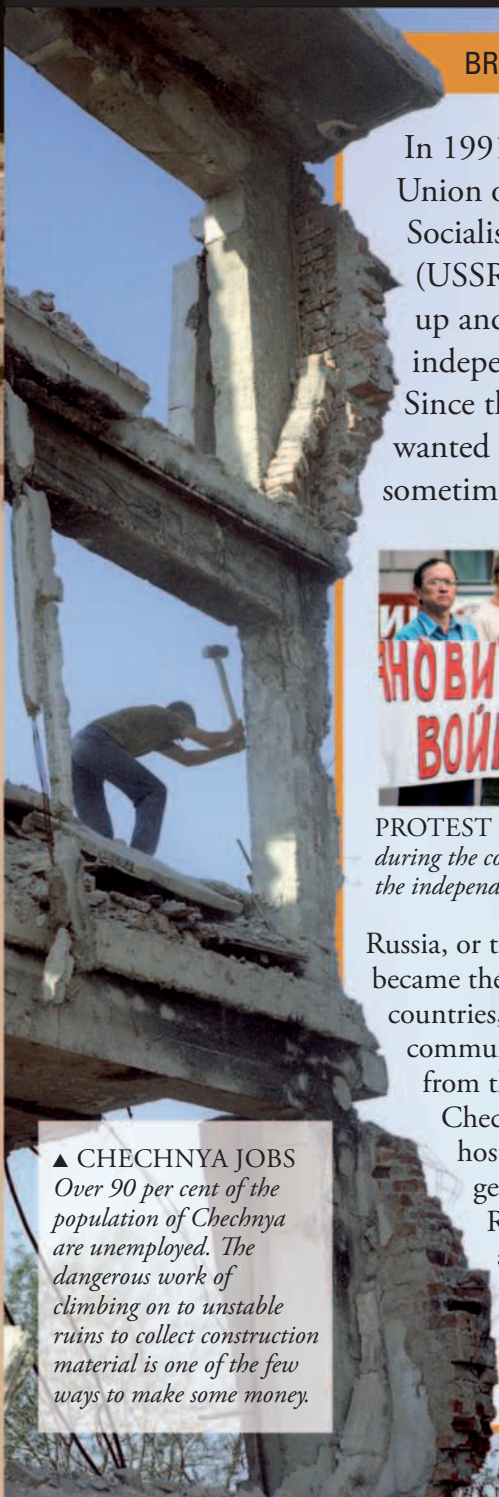
▲ **CHECHNYA JOBS**  
*Over 90 per cent of the population of Chechnya are unemployed. The dangerous work of climbing on to unstable ruins to collect construction material is one of the few ways to make some money.*

## CONFLICT IN AFGHANISTAN



The Taliban is an Islamic movement that ruled Afghanistan from 1996-2001. After the 9/11 attacks (see Fast Facts), Al-Qaeda leaders were believed to be sheltering in Afghanistan and this led to the country being attacked by the United States and its allies. They overthrew the Taliban government, but Taliban troops have continued to fight against the new government of Afghanistan and against the US and allied troops that are still stationed there.

▲ **GULF OIL FIELD**  
*The states around the Gulf have become super rich due to the oil revenue. The 300-mile (483-km) long oil field in Saudi Arabia is the world's largest.*





ISRAEL AND PALESTINE



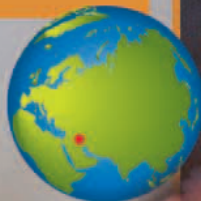
After World War II, the state of Israel was created as a home for Jewish people. The Palestinians also have claims to the land. Since then there have been wars between Israel and its Arab neighbors and in more recent years, many suicide bombings and other attacks between Israel and Palestinians.

The West Bank and the Gaza Strip are the two unconnected regions of the Palestinian territories. A network of fences, trenches, and high concrete walls have been constructed as a barrier around the West Bank and the Gaza Strip.



▲ BREACHING THE WALLS  
*The Palestinians in the Gaza Strip have made a number of attempts to cross into Egypt, seeking food and supplies.*

THE GULF REGION



The region around the Persian Gulf—a large bay that extends from the Indian Ocean—is the world’s largest source of crude oil. Any conflict in the region is an immediate threat to oil supplies around the world. Other countries are quick to intervene to safeguard the stability of the region and their own oil supplies.



**The 2003 Gulf War**

In 2003, the world was concerned that Iraq might be making dangerous biological and chemical weapons. A US-led multinational force rapidly defeated the Iraqi army and the authoritarian president was replaced by a new elected government.

*Coalition troops continued to be stationed in Iraq to support the democratic process and the rebuilding of the country.*

CENTRAL AND EAST AFRICA



Fighting between rebel groups and government forces in some countries in central and east Africa have forced many thousands of refugees to flee their homes. The area is also prone to environmental disasters, such as droughts or floods, causing food and water shortages.



*Refugees living in vast camps rely on food aid supplied by charitable organizations.*



TAKE A PICTURE

The United Nations (UN) organization aims to develop friendly relations between the countries of the world, bringing them together to solve international economic, social, cultural, and humanitarian problems.






# What is a government?


A government is a small group of people who make laws and decisions about how their country is run. They raise money from everyone in taxes and decide how this money is to be spent, such as on hospitals, schools, the army, prisons, and the building of new roads.

### ONE-PARTY STATE



In some countries, only one political party is allowed to exist; all others are banned. When there is an election, the one party decides who the candidates will be and the voters only get to approve that choice.


▶ **REPUBLIC OF CUBA**  
*The Cuban Communist Party is the only recognized political party.*



### WHO'S WHO?


- **President** A head of state of a republic with either extensive powers (as in the US) or limited powers (as in Germany).
- **Prime minister** The head of government in a parliamentary democracy.
- **Dictator** A ruler who has absolute power.
- **Monarchy** The hereditary rule of a single person. An absolute monarch has unchecked powers, while a constitutional monarch has limited powers.
- **Opposition** The parties that are not in a government and may disagree with the governing party.
- **Senate** The upper house of a legislative assembly (as in the US).
- **Cabinet** A group of ministers or others that advises a head of government.
- **Representative** A person who is elected to represent the public in making laws.

### MONARCHY



Many countries, like the UK, have a king or queen who acts as head of state but does not govern the country. However, there are a few countries where the monarch still holds all the power and governs the country. These “absolute monarchs” are not elected, but when they die, power passes to their son or daughter.

▲ **KINGDOM OF BRUNEI**  
*The Sultan of Brunei has absolute power.*



### MILITARY RULE



In some countries, if the government is weak or unpopular, the army seizes power and forms a military government. The country is governed by a military junta—a group of senior military officers, often with one particular general in control.

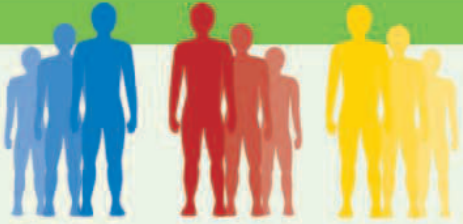
◀ **THE UNION OF MYANMAR**  
*In 1962, a military coup overthrew the Burmese government and since then a general has taken the position as head of state. All the cabinet roles are held by military officers. Ethnic struggles between the Government (junta), the Karen National Union, and the Mong Tai Army have continued.*



## NONDEMOCRATIC



MULTIPARTY DEMOCRACY



▲ THE CANDIDATES

*In an election, candidates may be nominated by different political parties. The person who gets the most votes is elected and the party with the most elected candidates forms the government.*

SYSTEMS OF GOVERNMENT

A constitution is a written document or unwritten code that establishes the structure and rules of the political organization of a country. Constitutional democracies may take the form of republics, as in France and the US, or constitutional monarchy, as in the UK and Spain. The country may have a presidential system (US), a parliamentary system (UK), or a semipresidential system (France).

▼ PROTESTS

*If people disagree with a bill, they will often organize protests to try to make their government take notice or change it.*



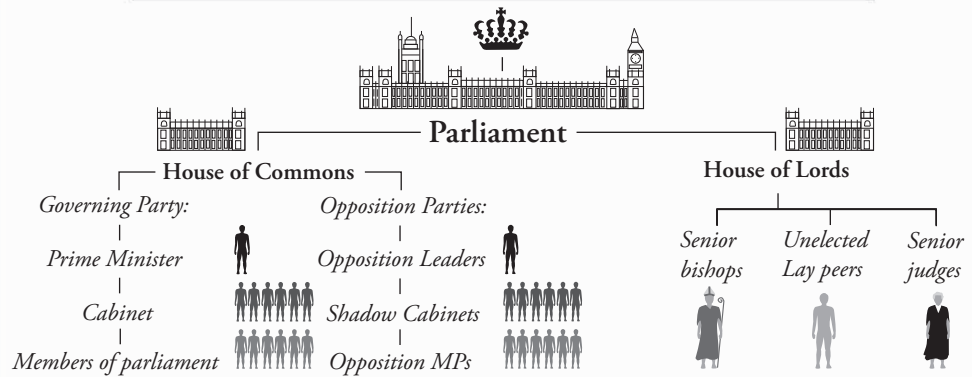
TAKE A LOOK: VOTING IN ELECTIONS

In a democracy, all adults are allowed to vote. On election day, they are given a piece of paper with the names of the candidates on it. They vote by putting a cross or a number next to the candidate's name. The voters deposit their voting slips into a locked ballot box. The votes are counted and the candidate with the most votes is elected to the position.



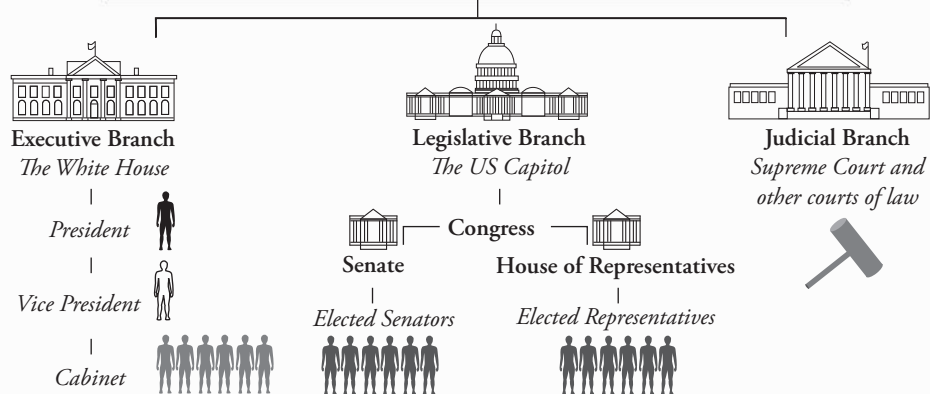
TYPES OF DEMOCRATIC GOVERNMENTS:

UNITED KINGDOM (UK) CONSTITUTIONAL MONARCHY



▲ UNITED KINGDOM (UK) *The monarch acts as head of state, but the parliament is responsible for making and changing the laws in the UK, which is done with the majority approval of both the House of Commons and the House of Lords.*

UNITED STATES OF AMERICA (US) CONSTITUTION



▲ UNITED STATES OF AMERICA (US) *The United States is the oldest constitutional republic and has three separate branches. The executive branch carries out the instructions of Congress, the legislative branch creates and changes laws, and the judicial branch manages the system of justice.*


DEMOCRATIC




# SCIENCE

- The word science comes from the Latin *scientia*, meaning knowledge.
- Scientific ideas were recorded by the philosopher Aristotle about 2,350 years ago.
- Sound waves with a frequency of 20,000 Hz or more are known as ultrasound.
- The universe is about 13.7 billion years old and is expanding at an increasing rate.
- The Earth's core is a solid iron sphere surrounded by a deep layer of molten iron.

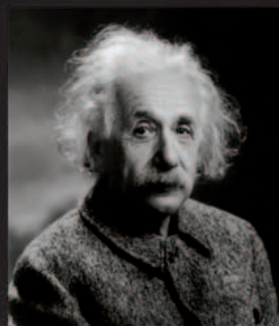


 How does a nutcracker crush a walnut? *Find out on page 233*



 What is terminal velocity and how does it affect a skydiver? *Find out on pages 234—235*





*Definition:* Science helps us understand the workings of the universe and everything in it. We increase our knowledge by observing, experimenting, and testing theories.

- Einstein's famous equation  $E=mc^2$  explains that energy and matter are the same thing.
- The Earth's climate is changing as a result of carbon dioxide produced by human activity.
- The instructions to make you are carried on about 25,000 genes in the DNA of your cells.
- In 1514 Copernicus was the first to show that the Earth moves around the Sun.
- Sound travels at a speed of 740 mph (1,190 km/h) through dry air that is 32°F (0°C).



Why do objects sitting in water seem distorted at the surface?

*Find out on page 241*



How do we get electricity from solar panels? *Find out on page 231*





# What is science?

Science is the search for knowledge about the world and the way it works. Unlike other ways of explaining how the world works, science is based on experiments that test theories (ideas).



◀ **JAPANESE MYTH** says that the gods stirred the ocean to create the first island.

## How does science work?

Science began when people started to check their ideas about the world. One of the first people to do this was an English doctor named William Gilbert (1544–1603). He performed many experiments on magnetism and eventually proved that the Earth is like a giant magnet.



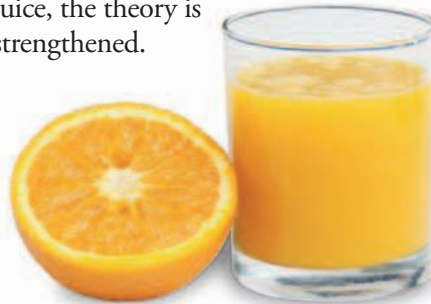
◀ **OLD MARINERS COMPASS** Gilbert showed that compasses point north because of the Earth's magnetism.

## BEFORE SCIENCE

In the past, people relied on ancient stories to explain such things as how life began, why the Sun appears to cross the sky, what lies beyond the oceans, and so on. These stories often came from religious books or from scholars who dreamed up imaginative ideas without checking them. Because the stories were never tested, there were hundreds of different versions, and every culture had a different version of the truth.

## Testing theories

Scientists begin with an idea, or “theory.” Imagine you have a cold but get better after drinking orange juice. You might form a theory that orange juice cures colds. To test this, you could give orange juice to people with colds. If they get better faster than people who don't drink juice, the theory is strengthened.



Orange juice



## TAKE A LOOK: COPERNICUS

■ One of the greatest ever scientific theories was put forward by Polish astronomer Nicolaus Copernicus in 1507. His idea was that Earth travels around the Sun, rather than vice versa. At first, people thought this was crazy because the Sun moves across the sky each day, as though it's going around Earth. But Copernicus discovered that this is an illusion caused by the Earth spinning around.

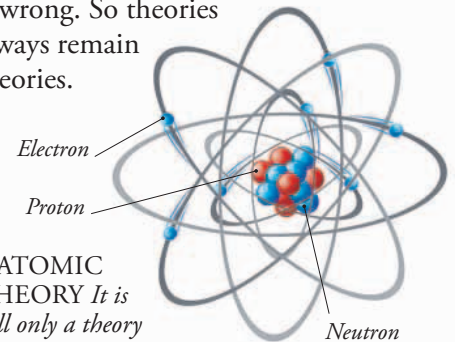


▶ **COPERNICAN WORLD SYSTEM** Pictures like this showed the Sun at the center of the universe for the first time.

## Proving theories

Although scientists can prove that a bad theory is wrong, they can never prove that a good theory is absolutely right. Even if a theory seems correct, someone could always do a new experiment in the future and prove it wrong. So theories always remain theories.

▶ **ATOMIC THEORY** It is still only a theory that matter is made of atoms.



## TIMELINE OF SCIENCE

c.350BCE

**Aristotle** is often called the first scientist. His ideas helped lay the foundations of modern sciences such as physics, chemistry, and biology.

1543

**Andreas Vesalius** was a Belgian who wrote a seven-volume book about the body.



1665

**Robert Hooke** was an English scientist. He used an early telescope to show that cells are the building blocks of all living things.

1687

**Isaac Newton** was a British scientist. He set out new ideas about motion and gravity.



1730–1880

Many scientists built on one another's work to understand electricity and turn it into a useful source of power.



## THE SCIENCES

Since science began over 2,000 years ago, our knowledge of the world has increased enormously. Science has led to many discoveries that have transformed society, such as cures for diseases. It's also led to amazing new inventions, such as telephones, televisions, space rockets, and computers. These practical spin-offs of science are called technologies.

### Medicine

Medicine is the science of healing illnesses. In the past, people believed that diseases were a punishment for bad behavior. Scientists now know that most diseases are caused by microscopic organisms, inherited genes, or faults with a person's immune system.



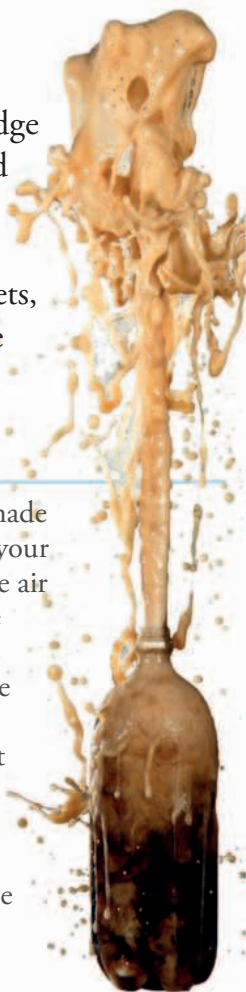
### Physics

Physicists investigate energy and movement. They study the tiniest particles of matter that make up atoms, and things that aren't made of matter at all, such as time, light, gravity, and space. The work of physicists led to the discovery of radio waves, which gave us television and cell phone technology.



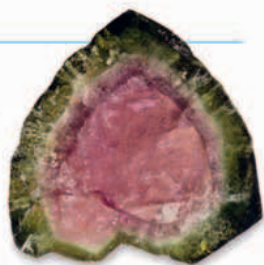
### Chemistry

All substances are made of chemicals, from your hair and teeth to the air around you and the paper in this book. Chemists investigate how atoms join together in different ways to form molecules, or how molecules break apart and recombine to form new substances.



### Geology

Geology is the study of the Earth and its interior. Geologists study how rocks form from chemicals called minerals and how they break down or change into new types of rock. Geologists also look at processes that happen deep underground in Earth's interior. These processes cause earthquakes and volcanoes, and continually reshape our planet's surface over long periods of time.



### Biology

Biology is the scientific study of living things. Its many branches are devoted to different kinds of life, including botany (the study of plants) and zoology (the study of animals). The most important idea in biology is the theory of evolution by natural selection, which explains how living things came to exist in their current form.



► **FOSSIL**  
*Preserved remains of living things helped scientists to understand evolution.*



### Astronomy

Planet Earth is a tiny speck of matter in a vast universe of planets, stars, galaxies, and colossal areas of empty space. Astronomy is the study of this gigantic realm beyond our own planet. Thanks to rocket technology, astronomers can now study space first hand.



1869

**Dmitri Mendeleev** was a Russian chemist. He laid the foundations of modern chemistry when he wrote the Periodic Table.

1890-1956

Scientists developed the atomic theory. They knew how atoms are put together and how they break apart.



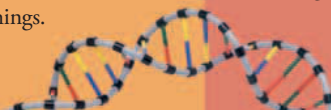
1905-1915

**Albert Einstein's** theories of relativity changed physics with new ideas about space, time, light, and gravity.



1953

**Francis Crick and James Watson** unraveled the structure of DNA, the genetic code inside living things.



1989

Internet Tim Berners-Lee invented the World Wide Web, a new way of sharing information.



# Mighty atoms

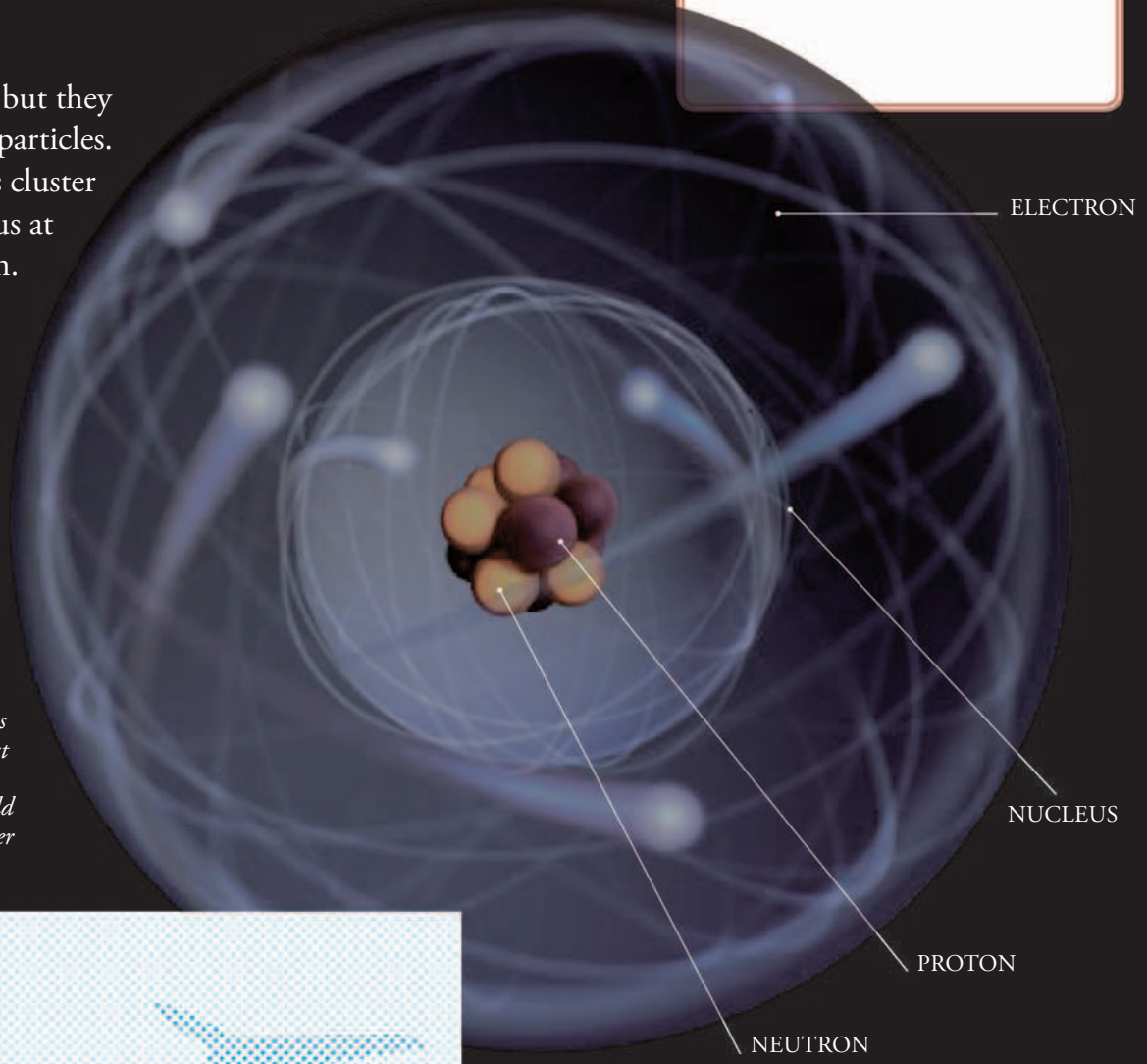
Everything is made up of atoms. These incredibly small particles are the building blocks of all matter, from the rocks that make up our Earth, and the animals, plants, and other creatures that live on it, to the planets and stars in distant galaxies.

**FAST FACTS**

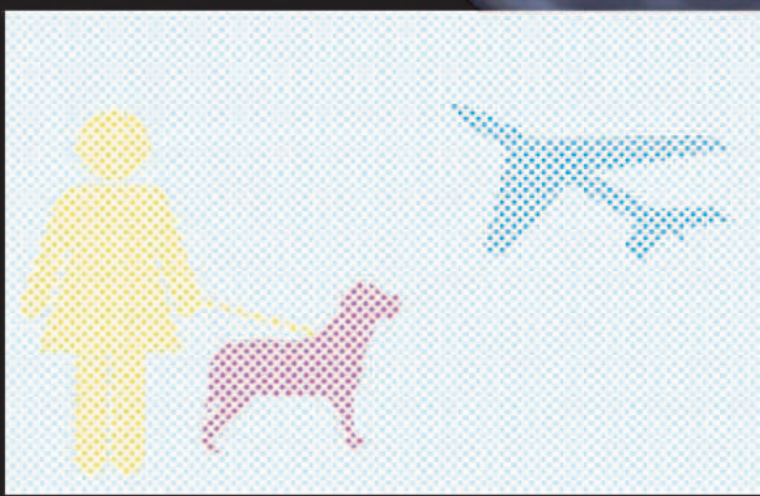
- The period at the end of this sentence covers around 250 billion atoms.
- Elements are made up of atoms that each have the same number of protons.
- Protons and neutrons consist of even smaller particles called quarks.

## INSIDE ATOMS

Atoms may be small, but they contain even smaller particles. Protons and neutrons cluster together in the nucleus at the center of the atom. Electrons move in a cloud that surrounds the nucleus. Strong electrical forces hold these small particles together inside atoms.



▼ **ATOMS** *Just as the images on a computer monitor consist of tiny dots of light called pixels, objects in the real world are made of tiny dots of matter called atoms.*



## LOOKING AT ATOMS

Atoms are too small to see. In fact, they are much smaller than the wavelengths of visible light, so a microscope is not much use either. Instead, scientists “see” atoms by taking pictures of the electric fields around these tiny particles.

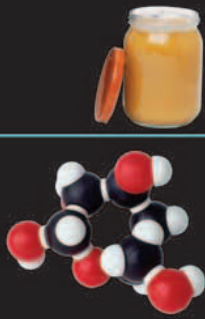


## Glucose



- Also known as dextrose
- First isolated from raisins in 1747 by Andreas Margaff

Plants make this simple sugar using the energy in sunlight. Animals eat these plants and other animals and then use the glucose in them as a source of energy to stay alive.



## Alcohol



- Also known as ethanol
- Formed by the action of yeast on natural sugars.

The word *alcohol* is the common name for ethanol, which is the type of alcohol found in beer, wine, and spirits. In concentrated form it kills germs. Doctors and nurses use it to clean the skin before an injection.



## Water



- Covers around 70 percent of Earth's surface
- Essential for life

Without water, life on Earth could not survive. This simple molecule makes up around 70 percent of the human body. Water is the only molecule that exists on Earth in three different forms—as a solid (ice), a gas (water vapor), and liquid (water).



## Vitamin B<sub>7</sub>

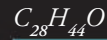


- Also known as biotin or vitamin H
- First isolated in 1941 by Vincent Du Vigneaud

Vitamin B<sub>7</sub> is one of eight molecules that make up the vitamin B complex. This essential vitamin is vital for cell growth. Sources include liver, brewer's yeast, and dairy products.

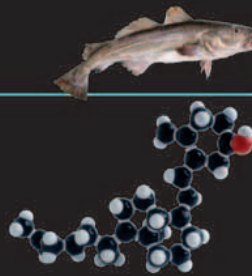


## Vitamin D



- Also known as cholecalciferol
- First isolated in 1922 by Edward Mellanby

Vitamin D is essential for building strong bones. This molecule is made in the body when the skin is exposed to sunlight. Other sources include cereals and fatty fish.

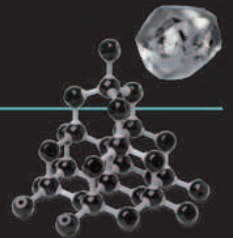


## Diamond



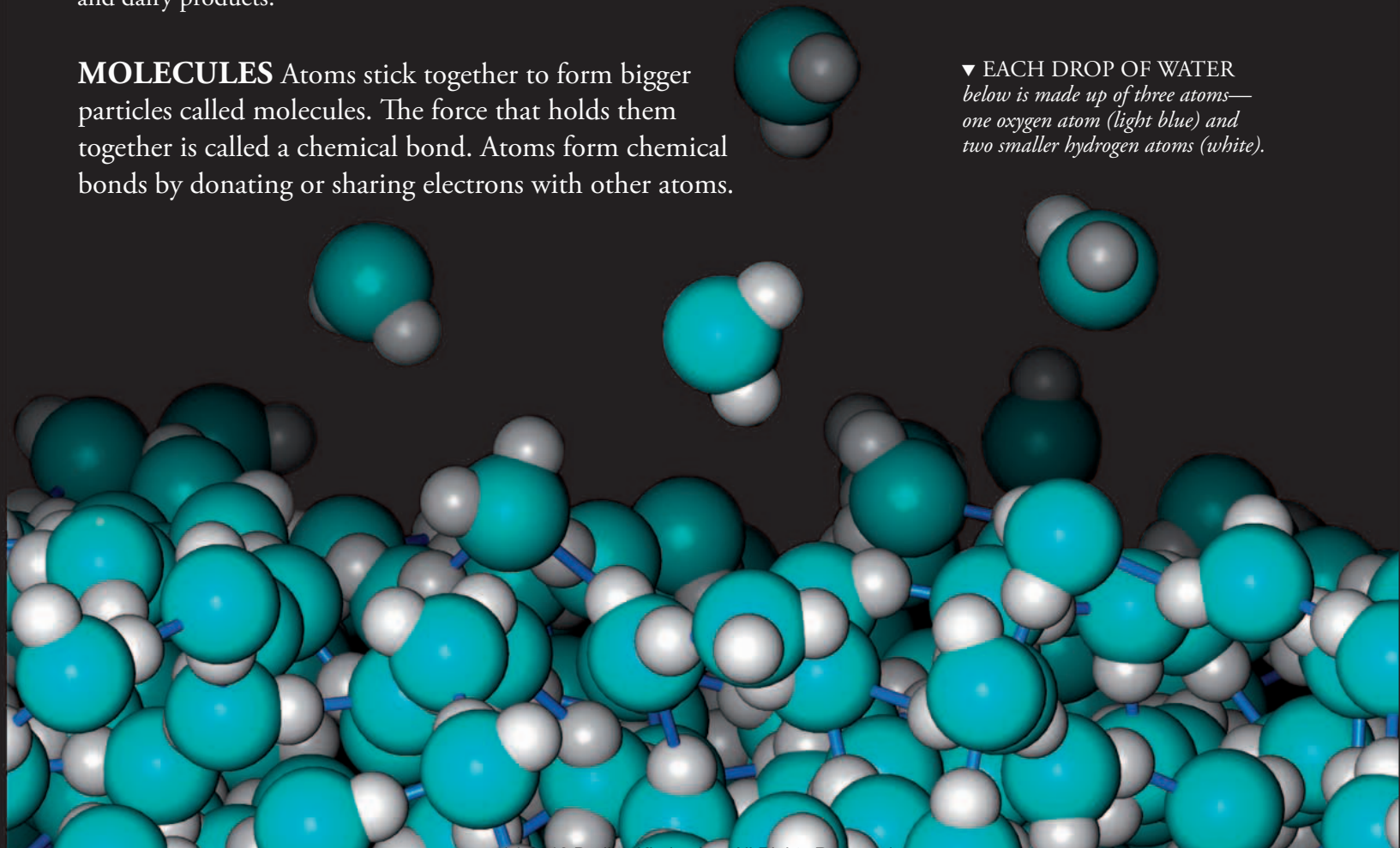
- Hardest known substance in nature
- Highly prized as a gemstone for jewellery

Diamond is a rare form of carbon in which each carbon atom bonds with four other carbon atoms to form a tightly packed crystal structure. Diamonds are very hard so they are used to make the tips of drills.



**MOLECULES** Atoms stick together to form bigger particles called molecules. The force that holds them together is called a chemical bond. Atoms form chemical bonds by donating or sharing electrons with other atoms.

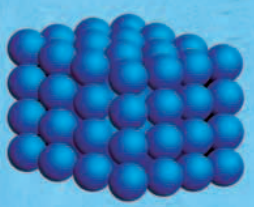
▼ EACH DROP OF WATER below is made up of three atoms—one oxygen atom (light blue) and two smaller hydrogen atoms (white).





# Solid, liquid, or gas?

Almost everything in the world exists in one of three states of matter. Solids keep a fixed shape, liquids have no fixed shape but fill the container in which they are held, and gases float around in space with no fixed shape or volume.



▲ **SOLID** *The atoms or molecules in a solid are packed tightly together.*

## SOLID STATE

The atoms or molecules in a solid substance are held together by electrical forces. They are arranged in a repeating pattern called a crystal lattice—similar to the way apples or oranges stack together in a grocery store. This makes the solid dense and hard.



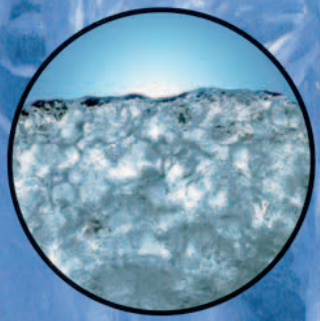
▲ **LIQUID** *The atoms or molecules in a liquid are packed less tightly than those of a solid.*

**SOLID TO LIQUID** *If you heat up an ice cube to its melting point, the solid ice gradually turns into liquid water. Ice melts at 32°F (0°C).*

Melting

Freezing

**LIQUID TO SOLID** *When the molecules in liquid water lose energy, they freeze and turn into solid ice. Water freezes at 32°F (0°C).*

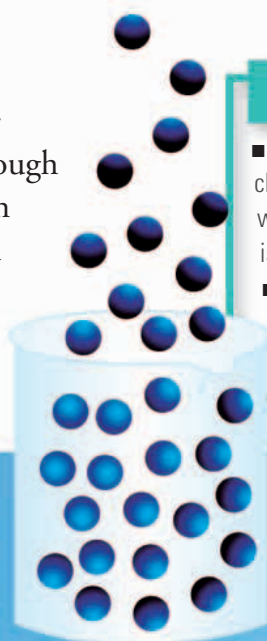


**Carbon crystals** A diamond is made up of many carbon atoms, which line up to form a crystal. The arrangement is so perfect that the carbon atoms are held very tightly. This makes diamond the hardest substance found in nature.



## CHANGING STATES

If you heat a solid enough, the atoms or molecules from which it is made get enough energy to break apart and slide over each other. The solid melts and changes from the solid state into the liquid state. Heat the liquid further, and it boils, changing into the gaseous state.



▲ **GAS** *The atoms or molecules in a gas are held so loosely that they fly away into space.*

### INTO THIN AIR

- Some substances, such as iodine, can change directly from a solid to a gas without first becoming a liquid. This is called sublimation.
- At room temperature, dry ice (frozen carbon dioxide) sublimates to become carbon dioxide gas.



## LIQUID STATE

The atoms or molecules in a liquid substance can slide over each other, so a liquid can be poured into a container. But the electrical forces between the atoms or molecules in a liquid stop them from pulling apart.

## GASEOUS STATE

The electrical forces between the atoms and molecules in a gaseous substance have broken down completely, so they will fill the container in which they are held. Gases cannot be poured like liquids, and many, but not all, are invisible.

**LIQUID TO GAS** *If you heat liquid water up to its boiling point, 212°F (100°C), the molecules evaporate (turn into a gas) and escape into the air.*

# Evaporation

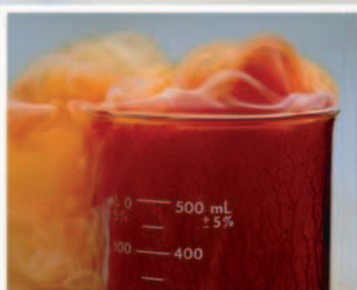


# Condensation

**GAS TO LIQUID** *When water vapor in the air loses energy, the molecules stick together and become liquid water.*



**Liquid metal** At room temperature, nearly all metals are solids. But there is one exception—mercury. Mercury has a melting point of  $-36.4^{\circ}\text{F}$  ( $-38^{\circ}\text{C}$ ), so it stays liquid—even if you put it in a freezer.



**Heating up** Solid aluminum reacts with liquid bromine to give solid aluminum bromide. The reaction produces a lot of heat, and the excess bromine boils. This produces brown fumes of bromine gas.



# Mixing chemicals

A few common substances are made of just one chemical, such as pure water or pure salt. Most of the things that we come across every day, however, are combinations of several chemicals.

## COMPOUNDS

Many substances undergo changes when they are mixed together. The chemical bonds that bind the molecules to each other break apart and then recombine to form new substances called compounds.

▲ **DISHWASHING LIQUID** *is a mixture of soap, water, and other chemicals.*

▲ **OIL AND WATER** *never combine because their molecules repel each other.*



## MIXTURES

Some substances do not react when they are added together because they cannot form chemical bonds. These are called mixtures. Mixtures can easily be separated again because the original substances do not change.

### TAKE A LOOK

■ Mixtures are made of different elements or molecules. During mixing, some of the substances may become harder to see. In coarse mixtures you can usually spot each substance. Suspensions may look like a single liquid, but eventually they separate out. Solutions are the most thoroughly mixed—it is often difficult to tell there is more than one substance.



▲ **COARSE MIXTURE** *In some mixtures the particles are large enough to be seen and separated easily. Gravel is a coarse mixture.*



▲ **SUSPENSION** *When small soil particles are mixed with water they form a suspension. Eventually the heavier solids will sink to the bottom.*



▲ **COLLOID** *These are like suspensions, but the particles do not sink to the bottom. In milk, tiny droplets of fat float in a watery solution.*



▲ **SOLUTION** *When one substance dissolves in another it is called a solution. Seawater is a solution of salt and water; air is a solution of gases.*



## SEPARATING MIXTURES AND COMPOUNDS

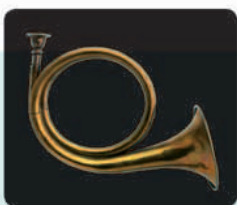
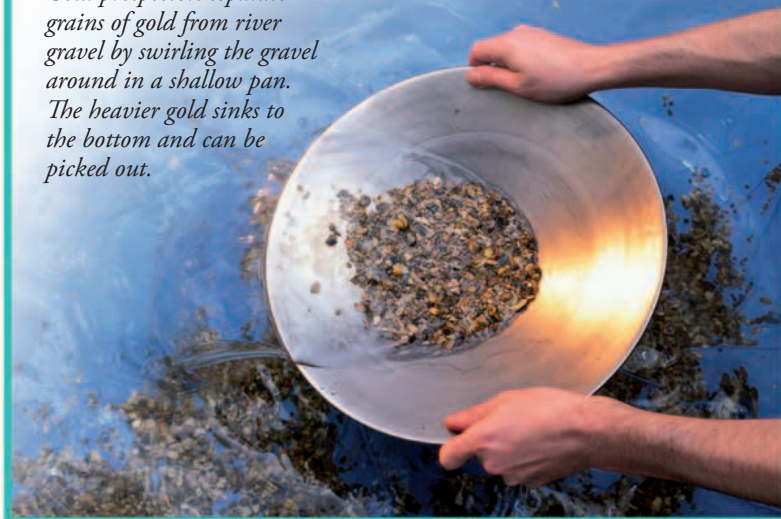
It is much easier to separate a mixture than a compound. Mixtures can be separated using physical methods, such as evaporation, filtration, flotation, or distillation. Separating compounds may require several steps before you get the substance you want, including mixing with other chemicals, heating, and filtering.



◀ **CHROMATOGRAPHY**  
This is used to identify colored substances in a mixture. A drop of the mixture is placed onto chromatography paper and solvent is then dripped onto it. As the solvent travels across the paper, the different substances travel across the paper at different speeds. Scientists can then figure out what each substance is by the distance it has traveled.

▼ **PANNING FOR GOLD**

Gold prospectors separate grains of gold from river gravel by swirling the gravel around in a shallow pan. The heavier gold sinks to the bottom and can be picked out.



▲ **ALLOY** This is a solid solution in which one metal has dissolved in another. Alloys are often tougher and more durable than the original metals.

**Irreversible reaction** Burning wood causes irreversible changes. The carbon atoms in the wood react with oxygen in the air to form ash, smoke, and carbon dioxide. The wood also loses energy as heat and light. Even if you put all these things together in a test tube they would not change back into wood. Another irreversible change happens when food starts to rot. Tiny microorganisms feed on the food and turn it into new substances. This process is called decomposition.

## CHEMICAL REACTIONS

When the atoms of two or more substances rearrange themselves to form a new compound, we say that a chemical reaction has taken place. Most chemical reactions are irreversible—you cannot turn a cake back into eggs and flour. Some reactions can be reversed but may need heat or pressure to change back.



▲ **IRON** can be prevented from rusting by coating it with a less reactive metal, such as zinc (left).



**Reversible reaction** When iron is exposed to air or water it starts to react. The metal reacts with oxygen, which turns the iron into the reddish brown iron oxides we call rust. However, if you were to heat the iron oxides in a blast furnace they would change back into iron and oxygen.





# It's elementary

An element is a pure substance that cannot be broken down into simpler chemicals. An element is made of only one type of atom. So, the element hydrogen is made only of hydrogen atoms, and gold of gold atoms.

## WHERE DO ELEMENTS COME FROM?

Most scientists believe that much of the hydrogen and some of the helium in the universe were formed in the "Big Bang" that formed the universe. Hydrogen has the smallest and simplest atoms, and helium has the next smallest.



## THE PERIODIC TABLE

Scientists recognize 117 different elements, which have been organized into a chart known as the Periodic Table. This table was first devised in 1869 by Russian chemist Dmitry Mendeleev, who organized elements with similar properties into groups. The elements are arranged by the size of their atoms.

Every element has a one- or two-letter symbol. For example, Kr is the symbol for the element Krypton. Scientists use these symbols to write down the chemical formulas for molecules and chemical reactions.

H HYDROGEN 1																	He HELIUM 2				
Li LITHIUM 3	Be BERYLLIUM 4															B BORON 5	C CARBON 6	N NITROGEN 7	O OXYGEN 8	F FLUORINE 9	Ne NEON 10
Na SODIUM 11	Mg MAGNESIUM 12															Al ALUMINIUM 13	Si SILICON 14	P PHOSPHORUS 15	S SULFUR 16	Cl CHLORINE 17	Ar ARGON 18
K POTASSIUM 19	Ca CALCIUM 20	Sc SCANDIUM 21	Ti TITANIUM 22	V VANADIUM 23	Cr CHROMIUM 24	Mn MANGANESE 25	Fe IRON 26	Co COBALT 27	Ni NICKEL 28	Cu COPPER 29	Zn ZINC 30	Ga GALLIUM 31	Ge GERMANIUM 32	As ARSENIC 33	Se SELENIUM 34	Br BROMINE 35	Kr KRYPTON 36				
Rb RUBIDIUM 37	Sr STRONTIUM 38	Y YTTORIUM 39	Zr ZIRCONIUM 40	Nb NIOBIUM 41	Mo MOLYBDENUM 42	Tc TECHNETIUM 43	Ru RUTHENIUM 44	Rh RHODIUM 45	Pd PALLADIUM 46	Ag SILVER 47	Cd CADMIUM 48	In INDIUM 49	Sn TIN 50	Sb ANTIMONY 51	Te TELLURIUM 52	I IODINE 53	Xe XENON 54				
Cs CESIUM 55	Ba BARIUM 56	LANTHANIDES or RARE EARTH 57-71		Hf HAFNIUM 72	Ta TANTALUM 73	W TUNGSTEN 74	Re RHENIUM 75	Os OSMIUM 76	Ir IRIDIUM 77	Pt PLATINUM 78	Au GOLD 79	Hg MERCURY 80	Tl THALLIUM 81	Pb LEAD 82	Bi BISMUTH 83	Po POLONIUM 84	At ASTATINE 85	Rn RADON 86			
Fr FRANCIUM 87	Ra RADIUM 88	ACTINIDES or RARE EARTH RADIOACTIVE METALS 89-103		Rf RUFORDIUM 104	Db DUBNIUM 105	Sg SEABORGIUM 106	Bh BOHRIUM 107	Hs HASSIUM 108	Mt MEITNERIUM 109	Ds DARMSTADTIUM 110	Rg ROENTGENIUM 111										
La LANTHANUM 57	Ce CESIUM 58	Pr PRASEODYMIUM 59	Nd NEODYMIUM 60	Pm PROMETHIUM 61	Sm SAMARIUM 62	Eu EUROPIUM 63	Gd GADOLINIUM 64	Tb TERBIUM 65	Dy DYSPROSIUM 66	Ho HOLMIUM 67	Er ERBIUM 68	Tm THULIUM 69	Yb Ytterbium 70	Lu LUTETIUM 71							
Ac ACTINIUM 89	Th THORIUM 90	Pa PROTACTINIUM 91	U URANIUM 92	Np NEPTUNIUM 93	Pu PLUTONIUM 94	Am AMERICIUM 95	Cm CURIUM 96	Bk BERKELIUM 97	Cf CALIFORNIUM 98	Es EINSTEINIUM 99	Fm FERMIUM 100	Md MENDELEVIUM 101	No NOBELIUM 102	Lr LAWRENCIUM 103							

Metals are on the left-hand side and center of the Periodic Table. On the right-hand side are gases and nonmetal solids.

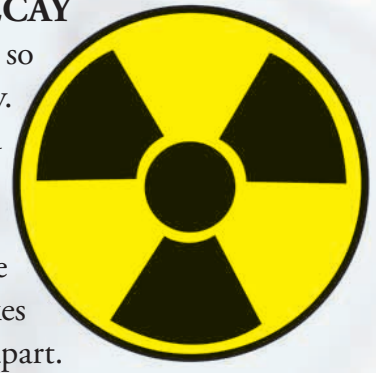
### Compounds

Most chemicals are not pure elements, but compounds. A compound is a chemical made up of two or more different elements chemically combined.

*Water is a compound made of two hydrogen atoms and one oxygen atom.*

## RADIOACTIVE DECAY

Some elements are made of atoms so large they break apart spontaneously. This is called radioactive decay, and the subatomic particles (smaller than atoms) and energy released by it can be dangerous. Each radioactive element has a half life, the time it takes for half of its atoms to break apart.







## Gold

*Aurum*

- **Group** Transition metals
- **Discovery date** Unknown (prehistoric times)
- **Melting point** 1,947°F (1,064°C)
- **Boiling point** 5,173°F (2,856°C)

Gold gets people excited. It has been prized and valued since prehistoric times and turned into many crowns, idols, and crosses over the centuries. Gold never loses its shine and is easy to melt and mold. It is measured in carats—pure gold is 24 carats.

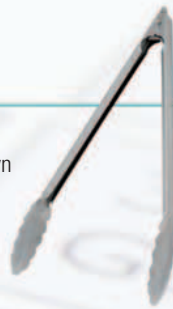


## Iron

*Ferrum*

- **Group** Transition metals
- **Discovery date** Unknown (prehistoric times)
- **Melting point** 2,800°F (1,538°C)
- **Boiling point** 5,182°F (2,862°C)

Iron is a versatile and abundant metal. We use it to build bridges and make machines and flatware. Iron is vital to your well-being. It gives red blood cells their color and helps to carry oxygen around your body. The center of the Earth is made of iron.

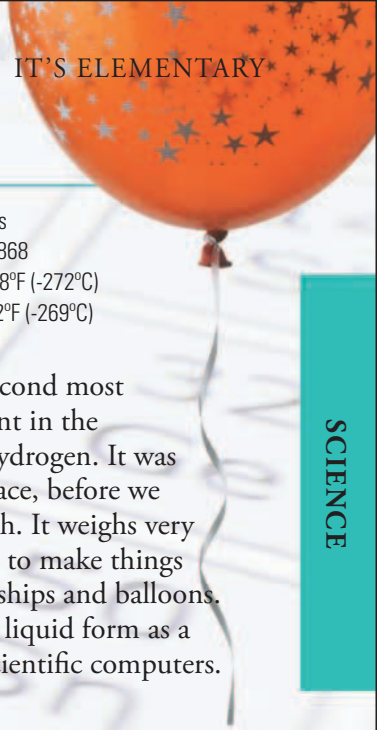


## Helium

*Helium*

- **Group** Noble gases
- **Discovery date** 1868
- **Melting point** -458°F (-272°C)
- **Boiling point** -452°F (-269°C)

Helium is the second most abundant element in the universe, after hydrogen. It was discovered in space, before we found it on Earth. It weighs very little and is used to make things float, such as airships and balloons. It is also used in liquid form as a coolant in big scientific computers.



## Mercury

*Hydrargyrum*

- **Group** Transition metals
- **Discovery date** Pre-1500 BCE
- **Melting point** -38°F (-39°C)
- **Boiling point** 674°F (356°C)

Mercury is poisonous, although in ancient times it was thought to have healing and life-giving properties. Early chemists (alchemists) once thought it held the secret to making gold. At room temperature, mercury is a liquid.



## Carbon

*Carbo*

- **Group** Nonmetals
- **Discovery date** Unknown (prehistoric times)
- **Melting point** diamonds 6,917°F (3,852°C) sublimates 8,672°F (4,800°C)

Carbon is vital to all living things, and on Earth it is frequently exchanged between the air, living things, and the soil, in a never-ending cycle. Carbon atoms can join together to make coal and diamonds, as well as with other elements to make more than 10 million compounds.

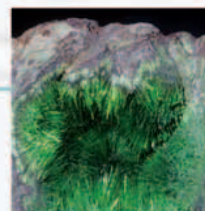


## Uranium

*Uranium*

- **Group** Actinides
- **Discovery date** 1789
- **Melting point** 2,070°F (1,132°C)
- **Boiling point** 7,468°F (4,131°C)

Uranium is a naturally occurring radioactive metal and was named after the planet Uranus. It is refined and used in industry, nuclear power plants, and warfare. In the 1940s it was used to make the atomic bomb “Little Boy,” which was dropped on Hiroshima in 1945.



## Calcium

*Calci*

- **Group** Alkaline earth metals
- **Discovery date** Pre-100 CE
- **Melting point** 1,548°F (842°C)
- **Boiling point** 2,703°F (1,484°C)

Calcium is the most abundant metal found in living organisms and is vital for many cellular reactions. It is also a key component of bones and shells, giving them strength. Calcium is also found in milk, chalk, and seaweeds.



## Phosphorus

*Lucifer*

- **Group** Nonmetals
- **Discovery date** 1669, by German chemist Hennig Brand
- **Melting point** 111°F (44°C)
- **Boiling point** 531°F (277°C)

This fiery element is very reactive and so isn't found naturally on Earth. Phosphorus is used to make matches, fertilizers, and some weapons. It is also a component of DNA and helps to make energy in your body.



### WHO'S WHO?

- **Robert Boyle** (1627–1691) was a British scientist who laid the foundation for modern chemistry and proposed the idea of elements.
- **Henry Cavendish** (1731–1810) was the first scientist to prove water was not an element, but a compound.
- **Joseph Priestly** (1733–1804) was a clergyman and scientist. He discovered several gases, including oxygen.
- **Alfred Bernhard Nobel** (1833–1896) was an explosives scientist. He created dynamite and founded the five Nobel prizes.
- **Marie Curie** (1867–1934) was famed for her work on radioactivity, and discovered polonium and radium.



# Energy

Energy is the power behind our world. Although you can't see it, you can't do much without it. Whenever things move, light up, change shape, get hotter or colder, or make noises, energy is involved.



*Freewheeling turns potential energy into kinetic energy.*

## STORED ENERGY

You can do two things with energy: store it or use it. It takes lots of energy to ride a bike up a hill, but that energy doesn't disappear. It's stored by your body and by your bike in a form called potential energy. You use this stored energy when you race back down without pedaling. The potential energy you stored is then converted into kinetic energy (movement energy).

## TYPES OF ENERGY

Energy exists in many different forms.

Almost everything we do involves changing energy from one form into another. When we're "using" energy, we're actually converting it into another form.



**Kinetic**  
*The energy moving things have. Race cars have lots of kinetic energy.*



**Light**  
*A kind of kinetic energy carried by invisible waves of electricity and magnetism.*



**Electromagnetic**  
*Electromagnetic energy is also carried by radio waves, X-rays, and microwaves.*



**Heat**  
*Hot things have energy because their atoms or molecules move more quickly.*



**Electrical**  
*Electricity is a convenient form of energy that can be carried along wires.*



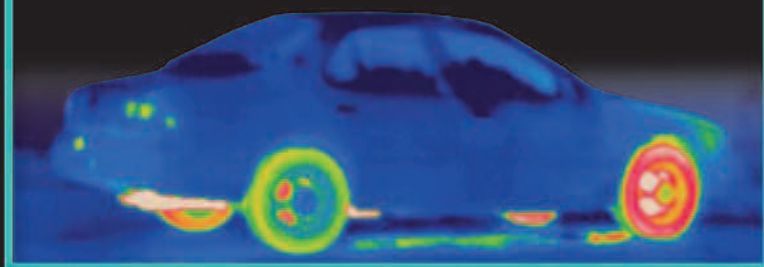
**Nuclear**  
*Atoms can release energy from their nucleus (central core).*



**Gravitational**  
*Falling things, like this waterfall, release potential energy stored using gravity.*

## CHANGING ENERGY

**Heat sensitive photograph** There's a fixed amount of energy in our universe. We can't make any more or use any up. All we can do is change energy to other forms. When a car brakes, its kinetic energy doesn't vanish. It changes to heat in the brakes and wheels (glowing in this heat-sensitive photograph).



## RENEWABLE ENERGY

Earth has limited amounts of fossil fuels, such as oil, coal, and gas. Once we've used them, there will be no more. There are unlimited amounts of renewable energy. This includes energy from the Sun, the wind, and the oceans. We can go on using renewable energy forever.



## ENERGY SOURCES

Most of the energy people now use (80-90 percent) comes from fossil fuels. The rest comes from renewable energy and nuclear power.

▼ **TURBINES** (*water wheels*) behind these channels generate electricity when water flows past them.



## Hydroelectric power

*Energy from moving rivers and seas*

- **Percentage of current energy use** 6 percent
- **Reserves left** Unlimited

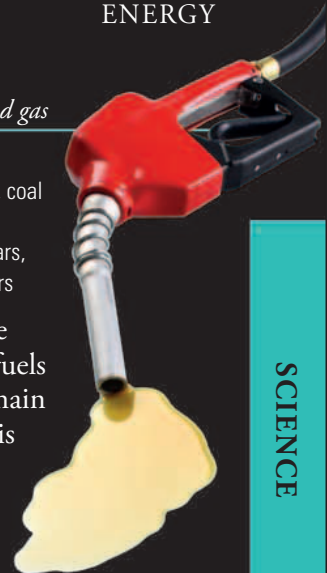
Rivers flow from mountains and hills down to the sea. This means they release stored potential energy. Hydroelectric power plants capture this energy to make electricity.

## Fossil fuels

*Energy from coal, oil, and gas*

- **Percentage of current energy use** Oil 38 percent, coal 25 percent, gas 23 percent
- **Reserves left** Oil 40 years, gas 100 years, coal 250 years

Although bad for the environment, fossil fuels are still the world's main energy source. Coal is cheap for making electricity, gas is easy to pipe to homes, and oil is convenient for powering vehicles.



## Geothermal power

*Energy from Earth's internal heat*

- **Percentage of current energy use** Less than 1 percent
- **Reserves left** Unlimited

Deep inside, Earth is hot molten rock. Some of this heat is released when volcanoes erupt. Geothermal energy means using Earth's inner heat to generate hot water and electricity.



## Biofuels

*Energy made using living plants and animals*

- **Percentage of current energy use** 4 percent
- **Reserves left** Unlimited

Growing plants and animals store energy we can use in the future. We can grow crops to make oil or make electricity by burning animal waste such as chicken manure. Energy made this way is called biofuel.



## Solar energy

*Energy made from the Sun's light or heat*

- **Percentage of current energy use** Less than 1 percent
- **Reserves left** Unlimited

Almost all the energy on Earth originally comes from the Sun. We can tap the Sun's energy directly to make electricity. Solar panels like these turn sunlight into electricity.



## Wave power

*Energy from the oceans and tides*

- **Percentage of current energy use** Less than 1 percent
- **Reserves left** Unlimited

Wind moving over the oceans stores energy in waves. Waves have kinetic energy (because they move) and potential energy (because they're above the normal sea surface). We can use the energy in breaking waves and shifting tides to generate electricity.



## Nuclear power

*Energy made from atomic reactions*

- **Percentage of current energy use** 6 percent
- **Reserves left** Raw uranium, 80 years

Atoms are made of tiny particles held together by energy. Large atoms can release this energy by splitting apart. Small atoms can release energy by joining together. Most nuclear power plants make electricity by splitting apart large uranium atoms.



## Wind power

*Energy from air currents moving across Earth*

- **Percentage of current energy use** Less than 1 percent
- **Reserves left** Unlimited

Wind turbines work like propellers in reverse. As their rotors spin in the wind, they turn small generators inside and make electricity.





# Feel the force

Forces are at work all the time, pulling you down to the ground, stopping you from slipping over, and pushing you one way and then the next. Forces act on everything, from the tiny nuclei inside atoms to the planets and stars that make up the universe.

## PULLING AND PUSHING

A force is a push or a pull. For example, your hand applies a pulling or pushing force to open and close a door. Forces act on all objects all of the time. They make them move or change their speed or direction.

*Your hand applies a pushing force on a toy car to make it move.*

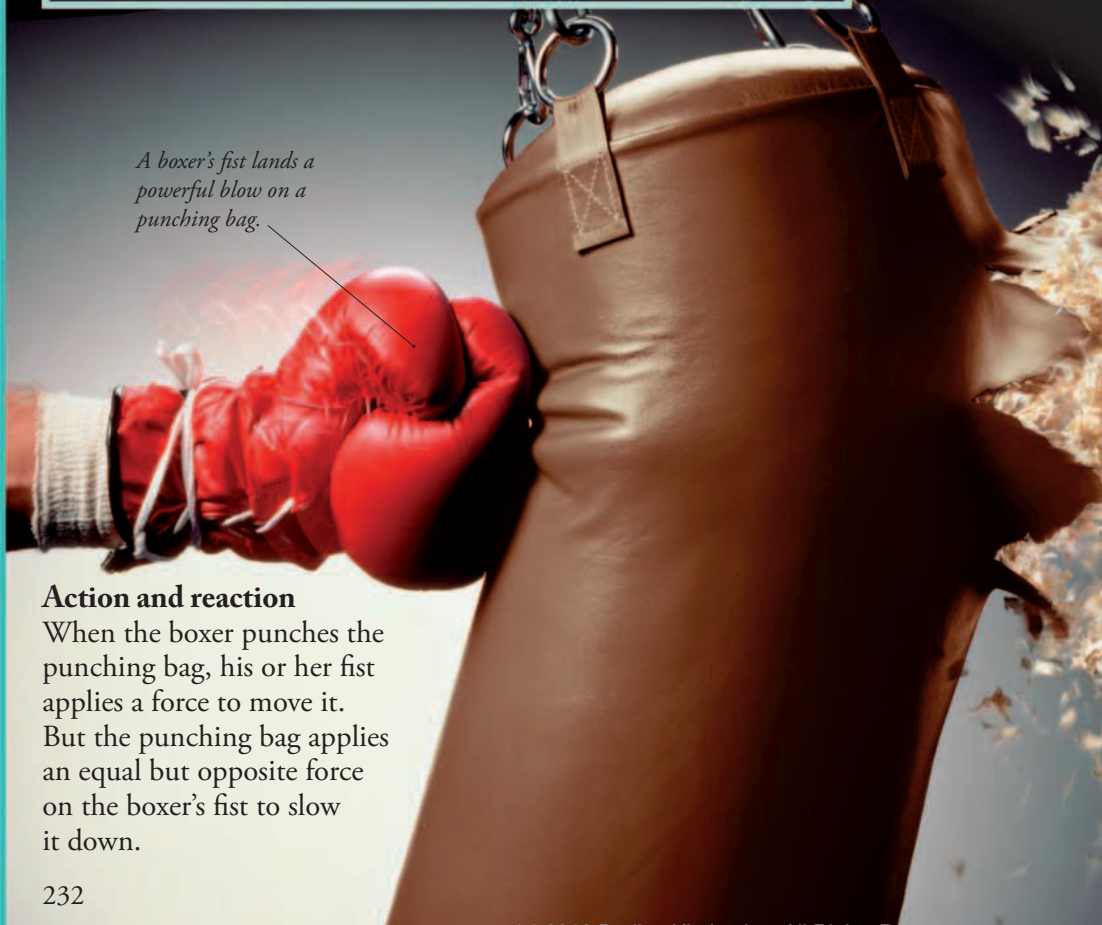


## HIDDEN FORCES

Usually you must touch an object to push or pull on it. But some forces act on things without touching them. For example, this magnet pulls on these paper clips with a magnetic force.



*A boxer's fist lands a powerful blow on a punching bag.*

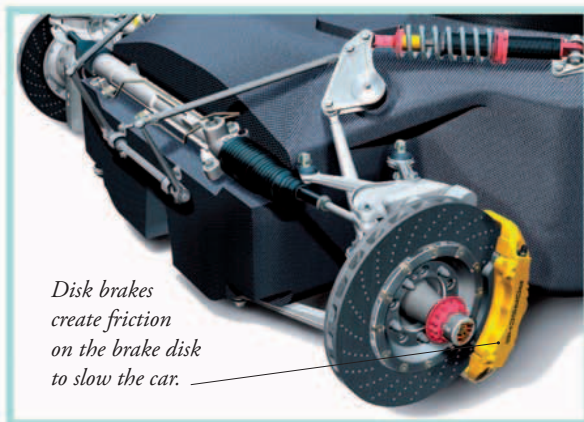


## Action and reaction

When the boxer punches the punching bag, his or her fist applies a force to move it. But the punching bag applies an equal but opposite force on the boxer's fist to slow it down.



**FRICTION FORCES** Roll a ball along the ground and eventually it will come to a stop. Friction acts on the ball to slow it down. Try to push a heavy box along the floor. Friction provides grip, making it hard to get the box moving.



Disk brakes create friction on the brake disk to slow the car.

**INERTIA** When there are no forces acting on an object, it will either stay still or keep moving in a straight line at the same speed. This is called “inertia.” In practice, friction usually slows down a moving object.



◀ **RUNAWAY CART!** When you let go of a shopping cart it continues moving under its own inertia.

### WHO'S WHO?

- **Aristotle** (c. 384–322 BCE) The ancient Greeks were the first to study forces. Aristotle came up with theories about how forces make objects move.
- **Archimedes** (c. 287–212 BCE) built war machines with levers to strengthen forces.
- **Galileo Galilei** (1564–1642) The Italian scientist studied forces by rolling different balls down ramps and shooting cannonballs through the air.
- **Sir Isaac Newton** (1642–1727) The English scientist came up with three laws of motion to explain how forces affect the motions of objects.



### LOTS OF LEVERS

▶ **YOUR FINGERS** grip the chopsticks at the pivot point. This reduces your gripping force but magnifies your finger movements.



### MAGNIFYING FORCES

People use machines to magnify forces. Machines called levers move around a fixed point called a fulcrum. Most levers magnify forces, but they act over a shorter distance than the force you put in. Simple levers include chopsticks, a pair of pliers, and a nutcracker.

Fulcrum

▶ **PLIERS** convert the weak force of your hand on one side of the lever into a stronger gripping force on the other side of the lever.



▶ **A NUTCRACKER** crushes a walnut by turning the weak force of your hand into a stronger force nearer the fulcrum.

Fulcrum



### BALANCED FORCES

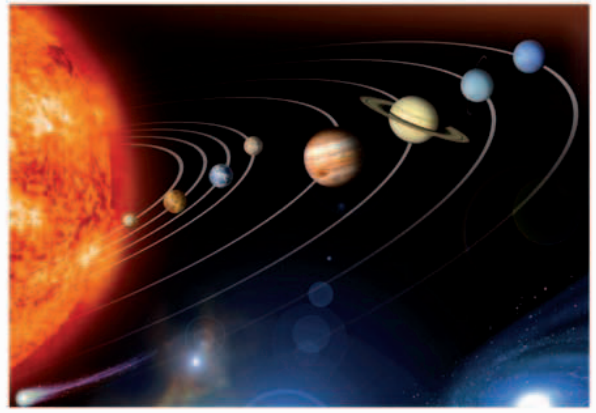
When two or more forces act on an object, they combine to produce a single “net force.” In some cases, the forces combine to make a larger net force. In other cases, the forces work against each other, resulting in a weaker net force. Sometimes the two forces cancel each other out completely.

◀ **TUG-OF-WAR** If both teams pull on a rope with the same force, the net force is zero and nobody moves.



# Gravity

Gravity is the force of attraction that pulls things together. On Earth, we experience it as the force that pulls us down onto the surface of the planet. In the universe, gravity is the force that pulls planets in orbit around stars.



## WEAK OR STRONG?

Gravity may seem impressive, but it is actually the weakest known force in the universe. It takes objects the size of planets and stars to produce a noticeable effect. The Sun's gravity is strong enough to hold all the planets of the solar system in orbit around it.

**Weight and mass**  
Weighing scales measure the pulling force that Earth's gravity exerts on your body. Gravity exerts more pulling force on a body with greater mass, so the scales would register a higher weight for a person with greater mass.



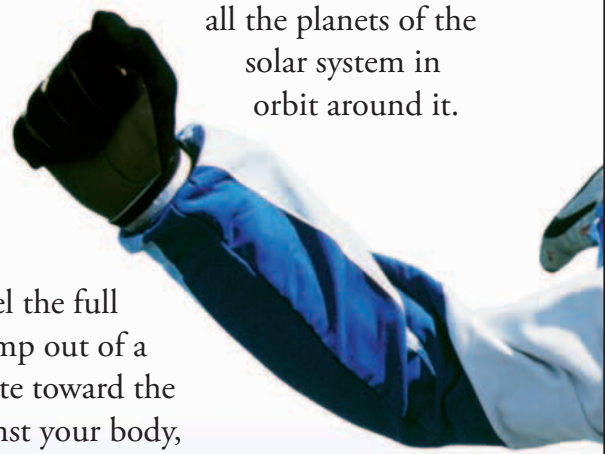
## GRAVITY AT WORK

Take up skydiving and you will soon feel the full effects of gravity at work. When you jump out of a plane, gravity makes your body accelerate toward the ground. At the same time, air rubs against your body, creating friction, or drag, which works against gravity. Eventually the two forces balance, and you stop accelerating—you have reached “terminal velocity.”

◀ *According to legend, Galileo dropped balls of different weights from the Leaning Tower of Pisa to show they hit the ground at the same time.*

## Gravity and Galileo

The first scientist to study gravity seriously was an Italian named Galileo Galilei (1564–1642). He did lots of experiments and concluded that in the absence of air resistance all falling objects would accelerate downward at the same rate. It is the air resistance, called drag, that allows some objects to reach the ground more slowly than others.



▲ **TERMINAL VELOCITY** *The highest velocity reached by skydivers with an unopened parachute is about 125 mph (200 km/h). Opening a parachute slows the skydiver down by increasing drag.*





## NEWTON

## ▼ SCIENCE GENIUS

*Sir Isaac Newton was the first person to figure out that the force of gravity keeps the Moon trapped in orbit around the Earth.*



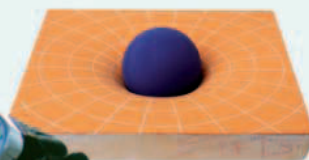
## ◀ APPLE IDEAS

*Legend has it that Newton came up with his theories about gravity when he saw an apple fall from a tree. He showed that the force that pulled the apple to the ground was the same force that pulled the Moon into the Earth's orbit.*

## EINSTEIN

## ▼ WARP FACTOR

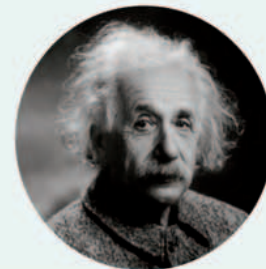
*Albert Einstein came up with another theory to explain gravity. He suggested that a big mass, such as a planet, warps space and time in the same way as a heavy ball resting on a rubber sheet.*



*The warping effect creates the force of gravity.*

## ▼ RELATIVE SUCCESS

*Einstein came up with his theory in 1916. A few years later, astronomers showed he was right, when light from a distant star was shown to bend as it passed the Sun.*

**Center of gravity**

Gravity pulls down on an object through a point called the center of gravity. An object will tip over if its center of gravity is too high or moves outside the base of the object. All-terrain vehicles have a very low center of gravity so they can drive up and down steep slopes.



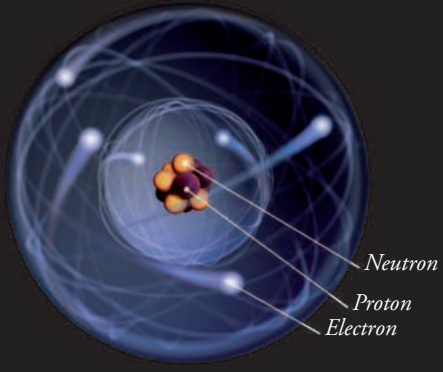
**Vomit Comet** Astronauts appear to float weightlessly in an aircraft as the plane follows the path that an object in free fall would take. In fact, the astronauts and the aircraft are accelerating at the same rate, but there is no contact between them. The plane is nicknamed the “Vomit Comet” because it makes some astronauts feel sick.

**EXPLODING STARS**

Stars are powered by nuclear reactions. In the core of the Sun, hydrogen atoms combine to form helium, releasing extreme heat. When the Sun runs out of hydrogen in its core, the core will collapse. The collapse of the core of a larger star might release enough energy that the star is seen as a supernova. The outer parts of the star are blown into space.







# Electricity

Everything in the universe is made up of atoms that we can't see. Each atom has particles that transport an electric charge. Electricity powers items we use every day, from lights to computers. It is carried to our homes by a series of cables and power plants.

**Charge carriers** Atoms contain particles that carry electrical charge. Protons are found in the nucleus and carry a positive charge. Neutrons are also found in the nucleus, but are uncharged. Electrons orbit around the nucleus.

## CHARGED CLOUDS

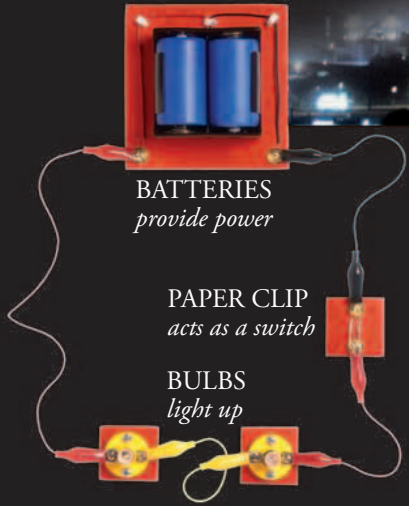
Lightning strikes when static electricity builds up in a storm cloud. Negative charge collects at the bottom of the cloud, while positive charge builds up near the top. Eventually, the negative charge shoots down to the ground in a bolt of lightning.



**Static electricity** The buildup of static electricity can make your hair stand on end. If you touch the metal dome of a Van de Graaf generator, positive charge transfers to your body, including your hair. The hairs repel each other, making them stand on end.

**TELL ME MORE...**

Static electricity can be very handy if you are a farmer. Crop spraying delivers pesticide as a spray of fine droplets. The spray is given an electric charge so that the droplets repel each other and spread out over the crops.



**Current electricity** Electrons can flow through metals and other conductors. This flow of electrical charge is called current electricity, and it can be used to light up our homes and power electrical devices such as microwaves and televisions.

**NERVES**

The nerves inside your body work like electric wires. They carry messages to and from the brain to different parts of your body in the form of electric signals.



# Magnetism

Whenever there is electricity, there is magnetism. This mysterious, invisible force draws some metal objects together or pushes them apart.

## WHAT CAUSES MAGNETISM?

The same moving electrons that create electricity also create magnetism. This force acts through an invisible magnetic field. You can see this field of force if you scatter some iron filings around a bar magnet.

*Like poles push apart*



### ▲ LIKE POLES REPEL

*Magnets have north and south poles. If you push the same poles together they repel each other.*



### ▲ UNLIKE POLES ATTRACT

*Push opposite poles together and a powerful force of attraction will snap the magnets together.*

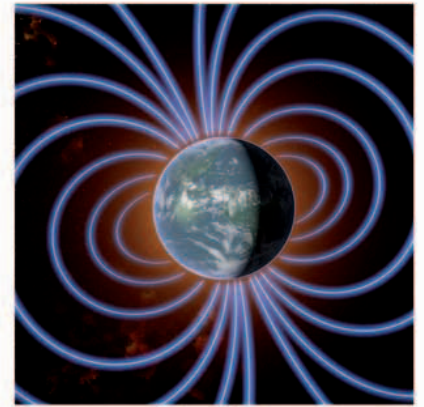


MAGNETIC NORTH POLE — MAGNETIC SOUTH POLE

**Electromagnetism** Magnetism and electricity are united by the force of electromagnetism. If you move a magnet next to a wire, electricity flows through the wire. Similarly, whenever electrons flow through a wire, they create a magnetic field around the wire.

◀ *ELECTRICITY flowing through the loops of electric wire inside an electromagnet generate a powerful magnetic field to lift scrap metal.*

*Compass aligns with the magnetic field of the bar magnet.*



**Natural magnet** Earth is a giant natural magnet whose magnetic field makes compass needles point toward the magnetic North Pole. Earth's magnetic field extends thousands of miles into space, forming a vast area known as the magnetosphere.



*A motor turns the blades of a food processor*

**Moving motor** Electrons flowing through a wire coil can make a magnet move in and out of the coil. Electrical energy changes into kinetic energy. This is how an electric motor works. Electric motors power devices ranging from computers to kitchen appliances.



# Science of sound

Sound is a form of energy. It passes through air, water, and solid objects as invisible waves. We can hear sound because the waves make the delicate skin of our eardrums vibrate. The vibrations are converted to nerve signals in our brains.



**Good vibrations** Objects can give out sound energy when they vibrate. This vibrating guitar string causes molecules of air to bump into each other. The collisions between molecules spread like ripples in a pool, carrying the sound outwards in all directions.

▶ **TUNING FORKS** vibrate at a particular frequency, so it always gives out sound at the same pitch.



**WOW!**

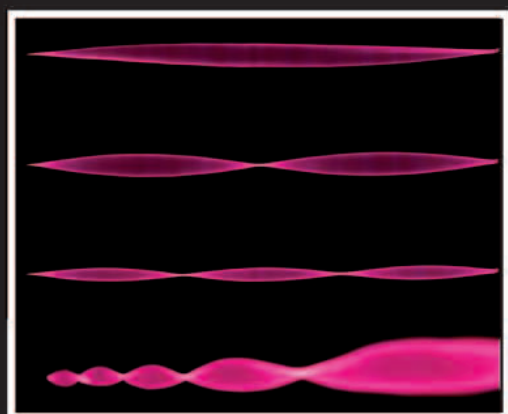
Sound waves travel through air at about 1,190 km/h (740 mph). This is slower than light waves, which is why we hear the sound of a distant jet aircraft or explosion after we see it. Sound travels faster under water, about 5,000 km/h (3,125 mph), though the exact speed varies with temperature.

▼ **PEAKS AND TROUGHS**  
The height, or "amplitude", of peaks and troughs in a sound wave dictates loudness.



## SOUND WAVES

We can't see sound waves, but we can get a good idea how they work by watching the way a wave travels along a glowing string. The end of the string is vibrated by a machine called an oscillator.



- ◀ **FREQUENCY 0.5 HERTZ** The string is vibrating with a long wavelength.
- ◀ **FREQUENCY 1 HZ** Vibrations in double time give shorter wavelengths.
- ◀ **FREQUENCY 1.5 HZ** At this higher frequency the wavelength shortens again.
- ◀ **FREQUENCY 2.5 HZ** High frequency sound waves make high-pitched sounds.

## TAKE A LOOK: DECIBEL SCALE

We measure the loudness of sound using the Decibel scale. This is what mathematicians call a "log scale", meaning the quietest sounds measure 0 dB, a sound ten times louder is 10 dB, a sound 100 times louder is 20 dB, and a sound 1,000 times louder is 30 dB.



▲ 0 dB  
The tiny sound of a finger brushing skin.



▲ 15 dB  
A whispered conversation.



▲ 60 dB  
A normal speaking voice.



▲ 90 dB  
The sound of a high-speed train passing by.



**Seeing with sound** Sound waves bounce off objects in the same way light waves do. Dolphins and bats are able to use these echoes to picture objects around them. With the aid of computer-imaging software that converts sound waves into pictures, we can do the same.



**Echolocation**  
*Seeing with sound*

**Bat calls** The echolocation calls produced by bats are loud but so high pitched that most people cannot hear them at all. Bats have incredibly sharp hearing and use faint echoes from nearby surfaces to pinpoint prey or detect obstacles.



◀ **FIRST PHOTO**  
*Advanced ultrasound scanners can produce amazingly detailed images such as this unborn baby.*



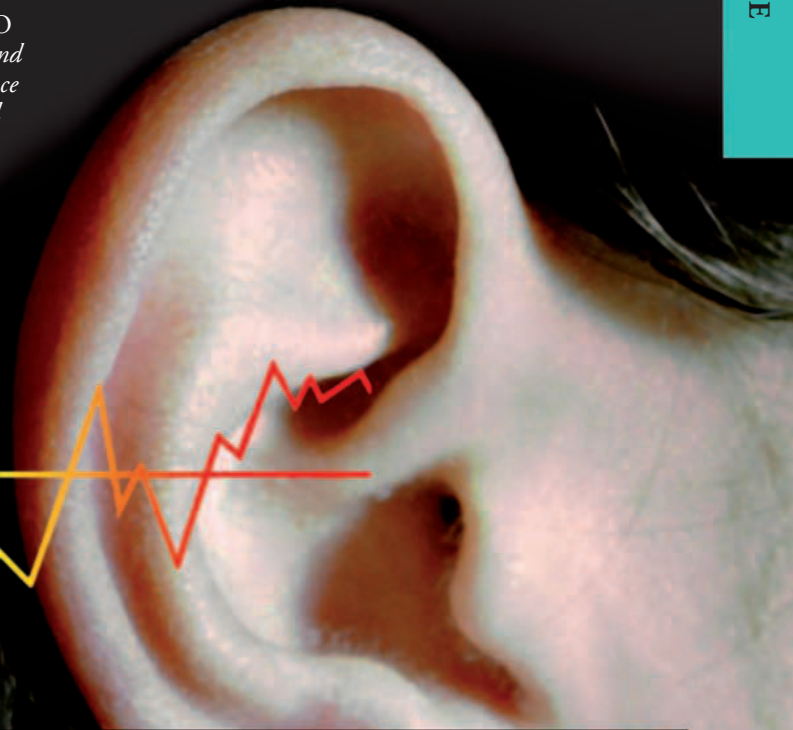
◀ **ULTRASOUND SCANNERS**  
*send out high-pitched waves and pick up the echoes to create an image.*



**Sonogram**  
*A sound diagram*

## PITCH AND TONE

The way we hear a sound depends on the shape of the sound waves. The spacing of waves affects the frequency or pitch of the sound. Closely packed waves indicate high pitch, while stretched out waves are low-pitched. A clear-toned sound like a bell creates smooth waves, while harsh tones such as drumbeats make jagged-looking waves.



*The “sonic shock” caused by a supersonic aircraft causes water in the atmosphere to condense, forming a visible cone, or collar, of vapor.*



▲ 100 dB  
*The blast of a car horn.*



▲ 110 dB  
*The sound of a thunderstorm overhead.*



▲ 120 dB  
*The roar of a jet aircraft taking off.*

## Breaking the sound barrier

When a supersonic aircraft breaks the speed of sound, it overtakes its own sound waves, pushing them closer together to create a “sonic boom”. A whipcrack is a type of sonic boom, caused when the whip tip breaks the sound barrier.

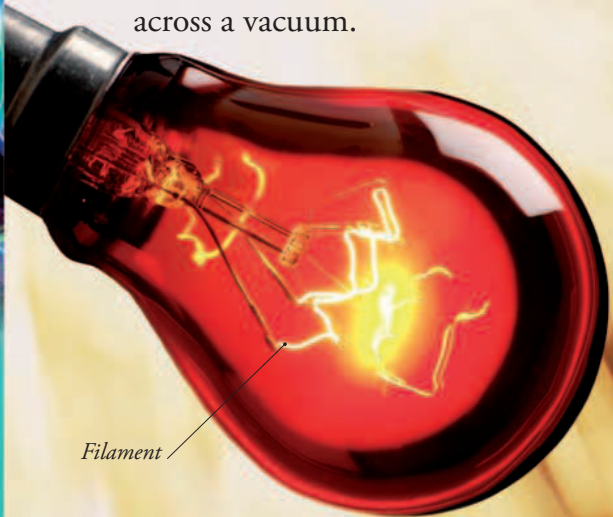
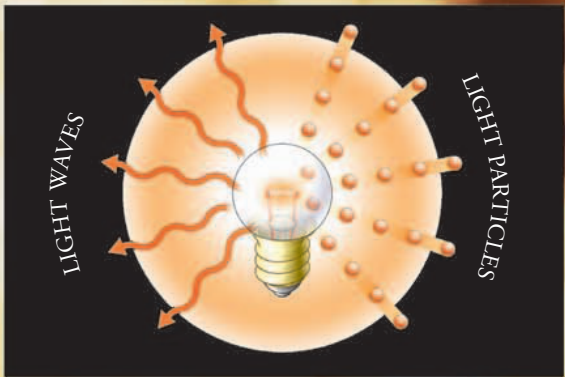


# Light fantastic

Energy takes many forms. Light is one we are familiar with because our eyes are specially adapted to detect it. However seeing light is one thing – understanding it is more tricky.

## HOW DOES LIGHT TRAVEL?

Puzzlingly, light behaves as though it is made of both waves and particles. Like waves, light can be reflected and refracted, and its wavelength can be measured. Other types of wave need something (a “medium”), to ripple through, but light can travel across a vacuum.



### Shadows

Light travels in a straight line, and cannot bend round obstacles. The space behind an obstacle looks dark because the only light reaching it is that reflected from other objects nearby.

A silhouette of a house made of small text characters. A dark shadow is cast behind it, illustrating that light travels in straight lines and cannot bend around the house.

## Where does light come from?

Atoms that are excited by a collision return to their normal state by emitting light energy. The atoms in a heated lightbulb filament shed their excess energy by flinging out tiny packets of light called photons, causing the filament to glow.

## THE SPEED OF LIGHT

- Light is the fastest moving thing in the Universe. It travels across empty space at the unimaginable speed of 300,000 km/second (186,411 miles/second).
- One light year is the distance light can travel in one year. This is about 9.5 trillion km (5.9 trillion miles). Light years are used to measure colossal distances across space. The Sun is a mere 499 light seconds away.
- Albert Einstein worked out that if there was a way to travel at close to light speed, time would slow down and you would age more slowly.

▼ ALL A BLUR  
*Fast-moving objects appear blurred because light travels much faster than our brain takes to interpret what we are seeing.*





**REFLECTION** When light strikes an object, some of it is bounced back or “reflected”. The angle of reflection is always the same as the angle at which the light hits the surface, so on a smooth surface we see a perfect reflection, or mirror image. If the surface is curved or uneven, the image is distorted.



*The break in the straws is an illusion caused by refraction.*

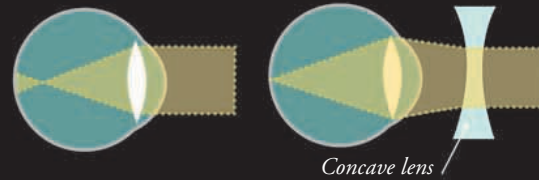


**REFRACTION** When light crosses the boundary between two media with different densities (such as air and water), it bends, or “refracts”. This is why objects standing in water appear distorted at the surface. If you try to touch a coin or pebble in a bucket of water, it will not be exactly where your eyes tell you it is.

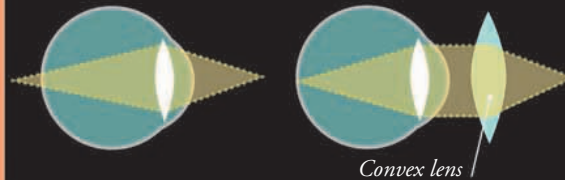
**Lenses** A lens is a transparent object with curved surfaces that refract light in a predictable way. An object close behind a bulging or “convex” lens will appear magnified while one seen through a dished or “concave” lens will appear reduced in size. Telescopes, microscopes, and spectacles all use lenses.



▶ IMPERFECT eyesight can be corrected with artificial lenses.



◀ **SHORT SIGHT** is when the eye focuses an image too far forward. It is corrected with a concave lens.



◀ **LONG SIGHT** causes the image to focus too far back, so the retina only detects a blur. It is fixed with a convex lens.

**FIREWORKS**  
*The atoms of different materials emit light of different colors or wavelengths. Firework makers use this to create wonderful displays.*



**Heat haze**

Refraction can happen when light passes through air of mixed density. Cool air over hot ground contains layers of variable density, and light passing through the layers is bent, causing a shimmering heat haze. In extreme cases the effect results in a “mirage” – a watery-looking reflection of the sky.



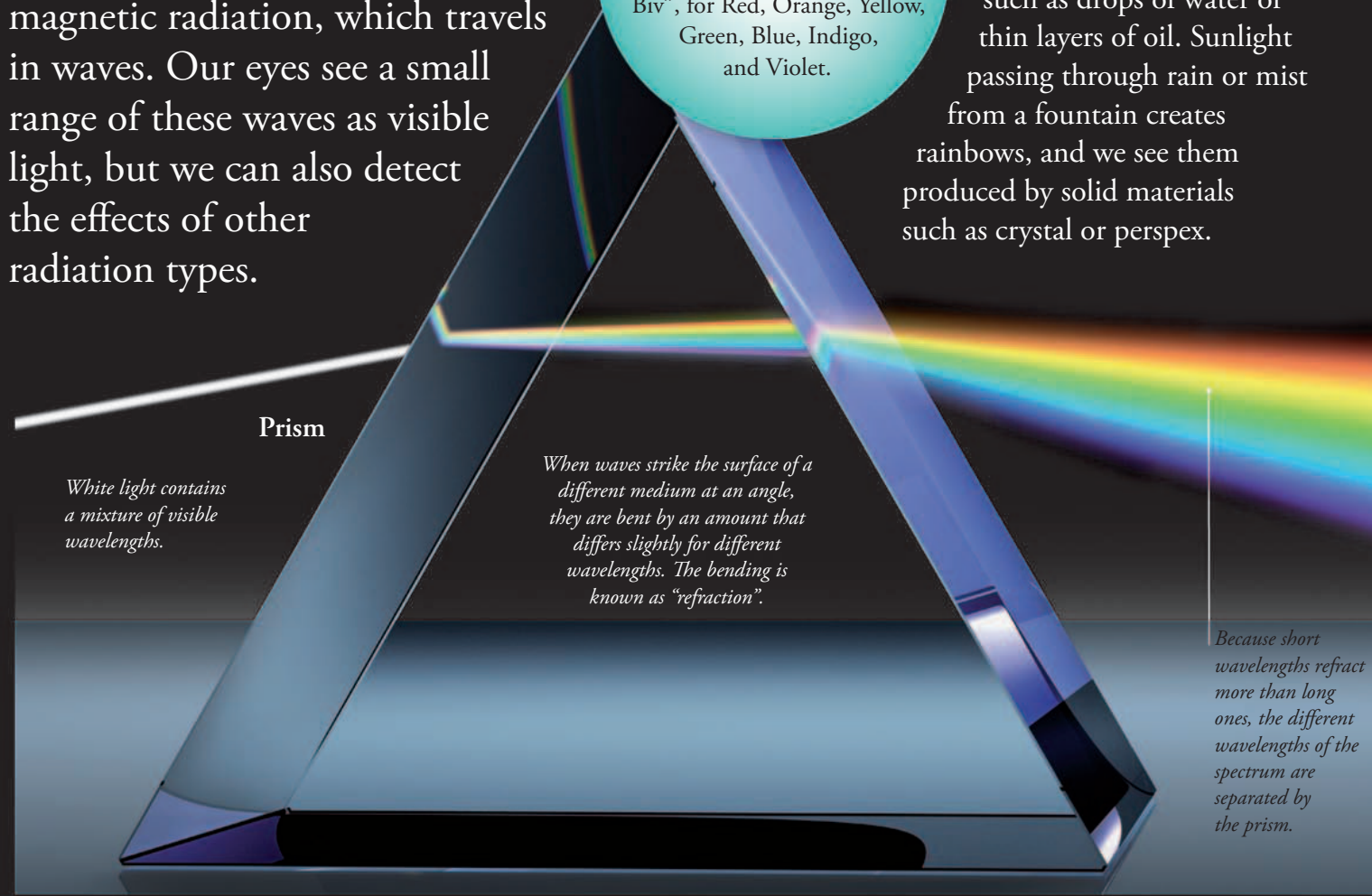
# Spectrum

The universe is full of electromagnetic radiation, which travels in waves. Our eyes see a small range of these waves as visible light, but we can also detect the effects of other radiation types.

**WOW!**  
To remember the colors of the visible spectrum in order, memorize this phrase: "Roy G. Biv", for Red, Orange, Yellow, Green, Blue, Indigo, and Violet.

## RAINBOWS

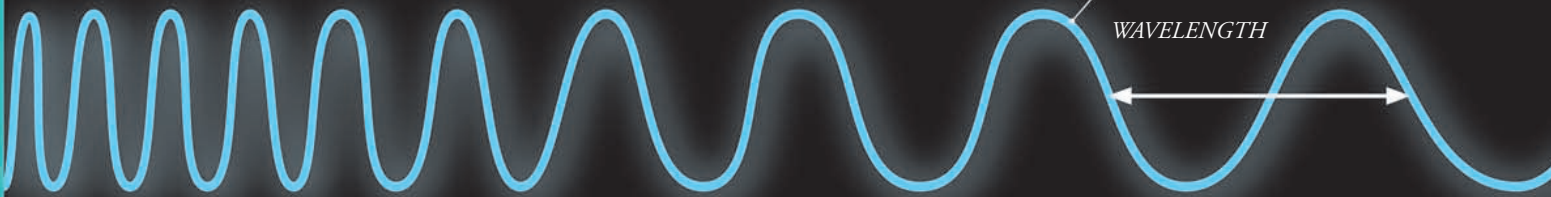
We see rainbows when white light is refracted as it passes through different media, such as drops of water or thin layers of oil. Sunlight passing through rain or mist from a fountain creates rainbows, and we see them produced by solid materials such as crystal or perspex.



## THE ELECTROMAGNETIC SPECTRUM

The visible spectrum is a small part of a much larger spectrum of energy waves. We have found technological uses for most types of electromagnetic radiation.

The wavelengths of different types of electromagnetic radiation range from shorter than an atom to millions of miles long.



GAMMA RAYS	X-RAYS	ULTRAVIOLET (UV)	VISIBLE RAYS
 <p>Gamma radiation is immensely powerful. In large quantities it damages our cells and DNA.</p>	 <p>X-rays pass through our bodies. We can use them to take pictures of our insides.</p>	 <p>Ultraviolet rays damage our cells. Sunscreen or a suntan can help filter them out.</p>	 <p>Visible light waves make the world a colorful place for us to experience and enjoy.</p>



## COLOR VISION

**Color vision** Objects appear colored to our eyes because their surfaces reflect some wavelengths of light but not others. Plants have chemicals called pigments that color their fruits and flowers, making them attractive to the animals that disperse their pollen and seeds. Most fruit-eating animals see in color.



*A tomato absorbs green and blue light and reflects red.*



*Lemons reflect red and green light, which we see as yellow.*



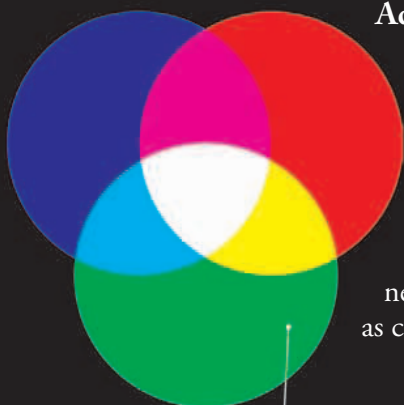
*Blackberries absorb all colors of light, reflecting very little.*



*Green peppers reflect green light and absorb red and blue.*

**Adding color**

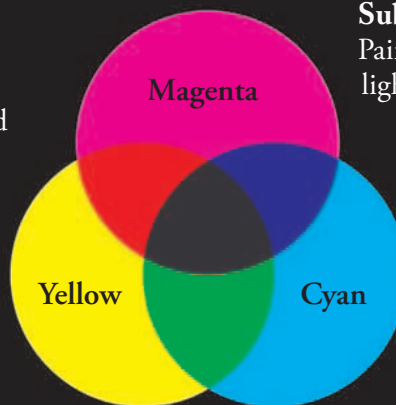
Televisions produce hundreds of colors by mixing red, green, and blue light in different quantities. Blending these three primary wavelengths to create new colors is known as color addition.



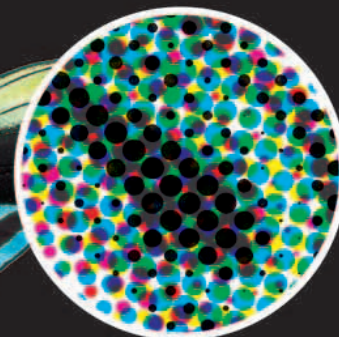
*You see green light because the ink used here absorbs all other color wavelengths.*

**Subtracting color**

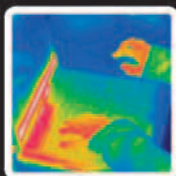
Paints create colors by absorbing light rather than emitting it. Mixing the primary paint colors of magenta, yellow, and cyan creates new colors by reducing the range of wavelengths that are reflected. This is called color subtraction.

**Unstoppable waves**

Electromagnetic radiation is everywhere. Visible light is bouncing off this page, allowing you to see the words and pictures printed in different colors. But other kinds of electromagnetic wave are passing straight through the pages and through your body without you even noticing.



▲ **COLOR PRINTING**  
*The microscopic dots used in color printing come in four colors, but blend to create the illusion of thousands more (👁️ p.168–169).*

**INFRARED (IR)**

*Warm objects emit IR radiation. IR cameras see heat as white or red. Cool objects appear blue.*

**MICROWAVE**

*Microwaves make certain molecules move very fast and give out lots of heat energy.*

**RADIO WAVES**

*Data, sound, and pictures can be transmitted as radio waves. Devices such as telephones,*



*radio, and TV sets convert the waves back into images and sound for us to see and hear.*



# Evolution

Over long periods of time, all species of organism slowly change. This gradual change, called evolution, is driven by the process of natural selection. This process allows organisms that are best suited to their environment to survive and reproduce.

## NATURAL SELECTION

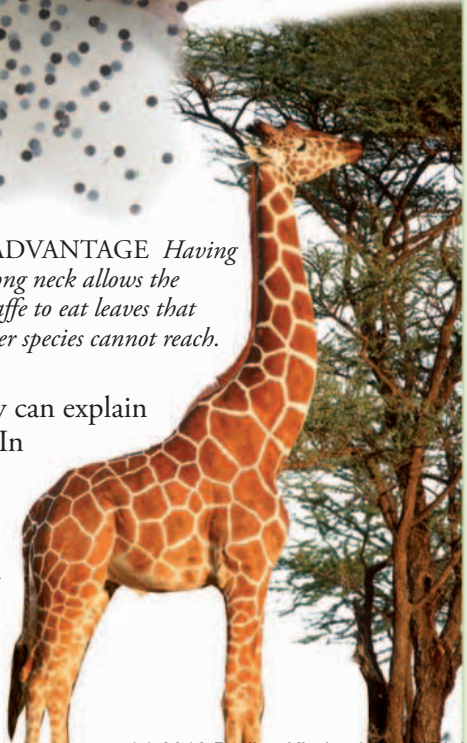
Darwin observed that most animals and plants produce more offspring than survive to become adults. He realized that nature was selecting those with the characteristics best adapted to their surroundings, allowing them to pass on their characteristics to future generations.



▲ **SURVIVAL TACTICS**  
Frogs produce hundreds of eggs but only a few grow into adult frogs.

▶ **ADVANTAGE** *Having a long neck allows the giraffe to eat leaves that other species cannot reach.*

**Adaptation** Darwin's theory can explain why a giraffe has a long neck. In the search for food, those that could reach a little higher had an advantage over those with shorter necks. Over time, new generations developed longer and longer necks.



**The father of evolution**  
The English naturalist Charles Darwin first proposed the theory of evolution after studying hundreds of different animals, plants, and fossils. He realized that many species were related and had a common ancestor. Modern DNA testing is now proving that his theory was correct.

## ARTIFICIAL SELECTION

In the wild, species evolve by natural selection. However, humans have been helping evolution by choosing animals and plants with desirable characteristics and breeding them to produce sheep with more wool, cows that give more milk, and crops that have better yields. This process is called artificial selection.

**Domestic dogs** All dogs are descended from wolves. Over time, humans selectively bred them for things like hunting or herding ability, speed, and size, so that we now have hundreds of different species.



Gray wolf



*These dogs all have a little bit of wolf in them.*



Broccoli (flowers)



Cauliflower (flowers)

Wild cabbage



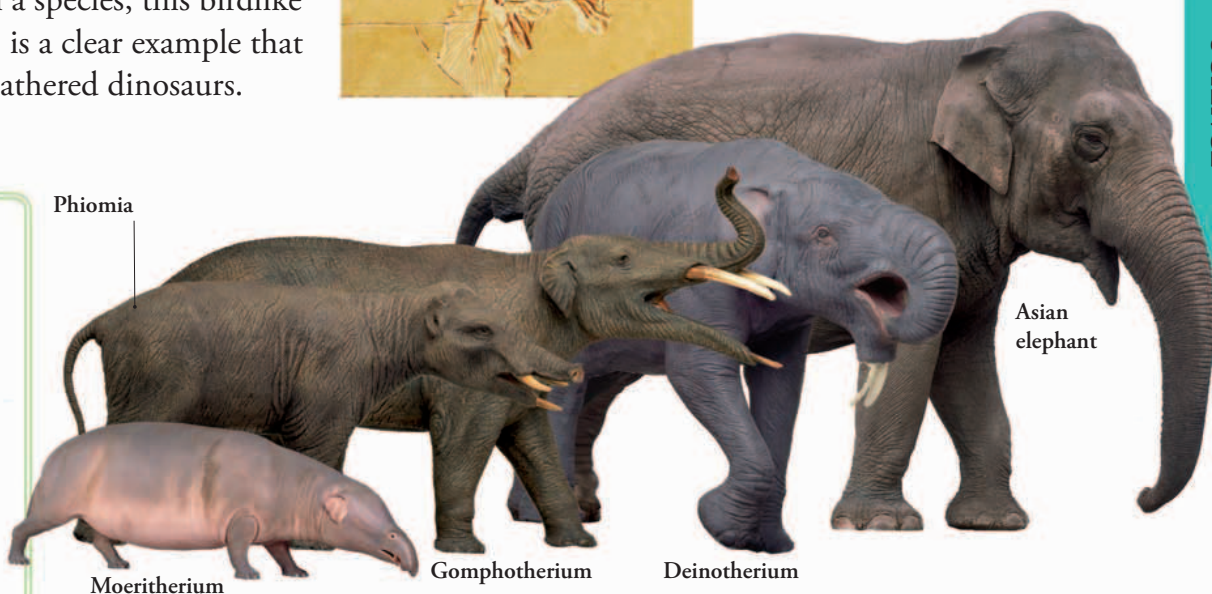


## THE FOSSIL RECORD

Fossils show that life on Earth has changed throughout its history. Each major layer of rock contains species that are slightly different to those below or on top of it. Although it is not easy to find fossils that show every change in a species, this birdlike *Archaeopteryx* (right), is a clear example that birds evolved from feathered dinosaurs.



**Family trees** Scientists trace evolution by examining fossils and seeing where they fit on the family tree. Many elephant fossils have been found that show how these animals developed tusks and a long trunk, but not all are direct ancestors of modern elephants.



SCIENCE

Brussels sprouts (large buds)



Red cabbage (leaves)



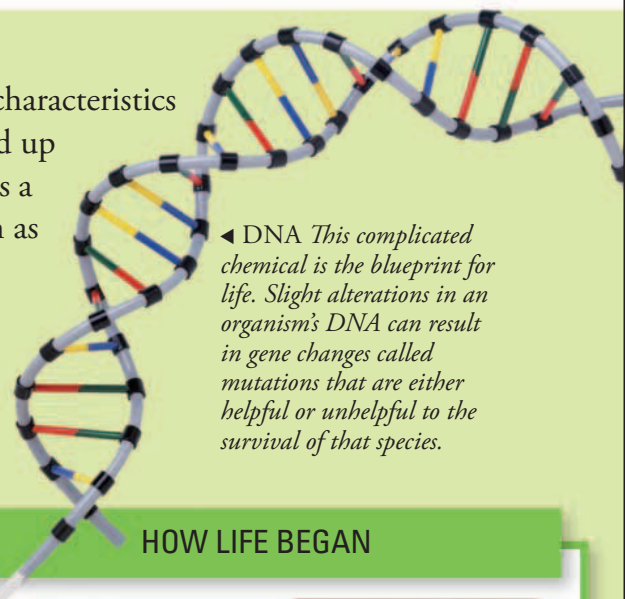
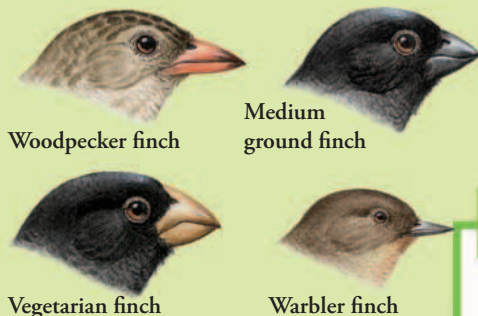
Green cabbage (leaves)



**Cabbages** These vegetables may look different but they are all descended from the wild cabbage. Cabbages, cauliflowers, broccoli, and Brussels sprouts have been bred for their leaves, flowers, or buds.

## EVOLUTION AND GENES

Organisms use DNA to pass on their characteristics to the next generation. DNA is divided up into sections called genes. Every gene is a code for a particular characteristic, such as hair, feathers, skin, or scales.



◀ **DNA** This complicated chemical is the blueprint for life. Slight alterations in an organism's DNA can result in gene changes called mutations that are either helpful or unhelpful to the survival of that species.

## HOW LIFE BEGAN

It remains a mystery how life began. Earth was so hot that life began in the oceans, perhaps around vents in the ocean floor (right). Simple molecules began to copy themselves, then formed into cells and colonies, and finally, complicated organisms.



**New species** When Darwin visited the Galápagos Islands, he noticed that all the finches looked like a species on the mainland but had different beaks. He realized that all these new species had evolved from the same parents, but their beaks had changed to suit the food sources on each island.



# Genes and DNA

**WOW!**

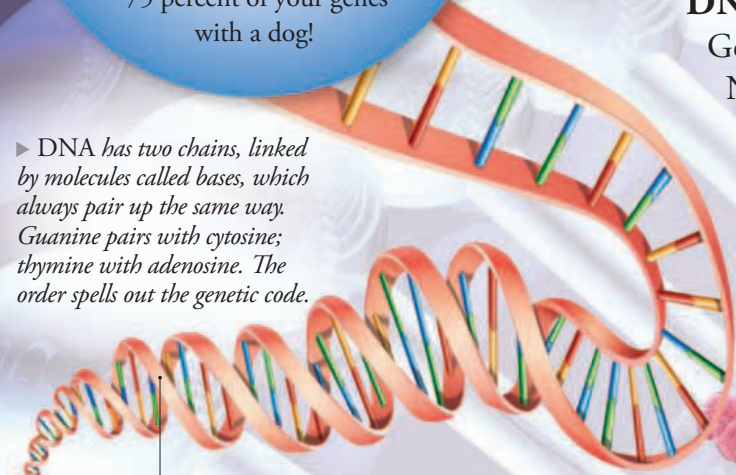
There are about 30,000 genes in the human genetic code. Some appear just once and others repeat many times. About 99 percent of human genes are identical to chimpanzee genes. Even more amazingly, you share about 75 percent of your genes with a dog!

Unless you are an identical twin, your body is built according to a unique set of biological instructions, your own genetic code. These instructions, or genes, are present in all cells and are passed from parent to offspring.

## DNA FOR DUMMIES

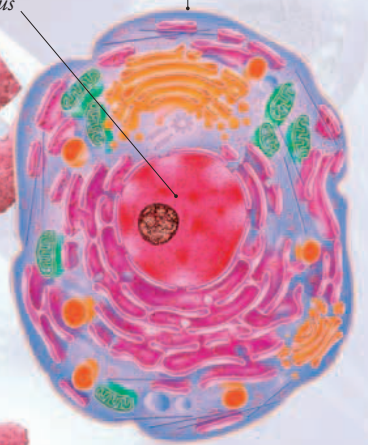
Genes are made of a substance called Deoxyribose Nucleic Acid, or DNA. DNA is a very long molecule, found packed up tightly in the chromosomes in the nucleus of every cell.

▶ DNA has two chains, linked by molecules called bases, which always pair up the same way. Guanine pairs with cytosine; thymine with adenosine. The order spells out the genetic code.



DNA

Nucleus  
Cell membrane



Chromosomes

▲ CHROMOSOMES Human beings normally have 46 chromosomes in every cell, except gametes (egg and sperm cells), which have just 23.

▲ CELL All living things are made of cells. When cells divide, the nucleus divides, too, and the genetic message is duplicated in each new cell.

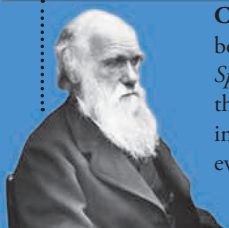
## IN THE GENES

If a person inherits two different genes from their parents, often one will dominate the other. For example, the gene for brown eyes overrides the one for blue eyes.



## TIMELINE OF MEDICINE

1859



Charles Darwin's book *Origin of Species* outlines the importance of inherited traits in evolution.

1860

Gregor Mendel's experiments on pea plants prove the existence of genes.

1869

Friedrich Miescher extracts DNA from cells. He calls it "nuclein."

1953

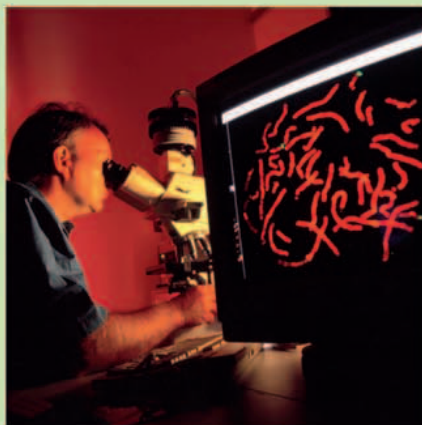


James Watson and Francis Crick discover the structure of DNA and show how it can copy itself.



## TAKE A LOOK: GENOME

■ A genome is the entire genetic code inside an organism. The first genetic code to be sequenced in full was that of a virus known as bacteriophage phi X174, in 1975. In 1984, the first bacterial genome was sequenced, and in 1990 scientists began to sequence the human genome. The project took 13 years to complete. They found that the genes were padded out by sequences of “junk DNA,” which had no obvious function. The human genome contains about three billion base pairs and codes for roughly the same amount of data that can be fit on one CD.



▲ THE CHROMOSOMES in this preparation have been treated to make a particular gene glow green.

**GM crops** Genes can be transferred into plants to create transgenic, or “genetically modified” (GM) crops. GM technology has been used to produce rice enriched with vitamins, corn and cabbages that produce their own insecticides, and soybeans that survive being treated with weedkillers that kill all other plants.



▲ CHEMICAL CURE In the future, GM crops should reduce the need to treat fields and orchards with chemicals that may harm the environment.

▲ CYSTIC FIBROSIS is caused by a mutation in a gene controlling the production of sweat and mucus.

**Genetic diseases** Some genes contain errors that cause them to malfunction. These faulty genes can cause diseases such as cystic fibrosis and sickle cell anemia. Most disease genes are “recessive,” like the gene for blue eyes, meaning the disease only develops if a child inherits a faulty copy from both parents.

## FACT FILE

■ Scientists can “cut and paste” genes from one species into another to create useful characteristics. The genetically altered organism is described as “transgenic.” Transgenic bacteria are used to produce useful drugs, and transgenic mice are used to research cures for many diseases.



▲ GLOW FOR IT These mice were given a jellyfish gene to make them glow in the dark.

**Cloning** means using DNA from an organism to create an identical new individual, or clone. Some clones occur naturally—many plants and some simple animals reproduce by cloning, and identical twins are clones. Artificial cloning can be used to grow new organs for transplant patients.

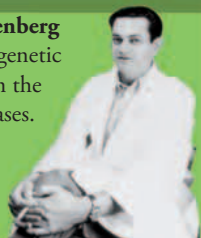
## ▶ DESIGNER BABY

Would you pick and choose which genes to pass on to your children?



1961

Marshall Nirenberg deciphers the genetic code hidden in the order of the bases.



1970

Frederick Sanger begins sequencing DNA.



1990

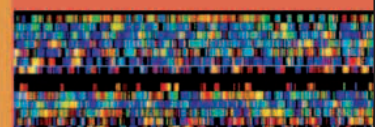
Doctors use gene therapy for the first time, treating a four-year old girl suffering from an immune disorder.

1996

The first experimentally cloned mammal, Dolly the sheep, is born.

2003

The completed sequence of the human genome is published.





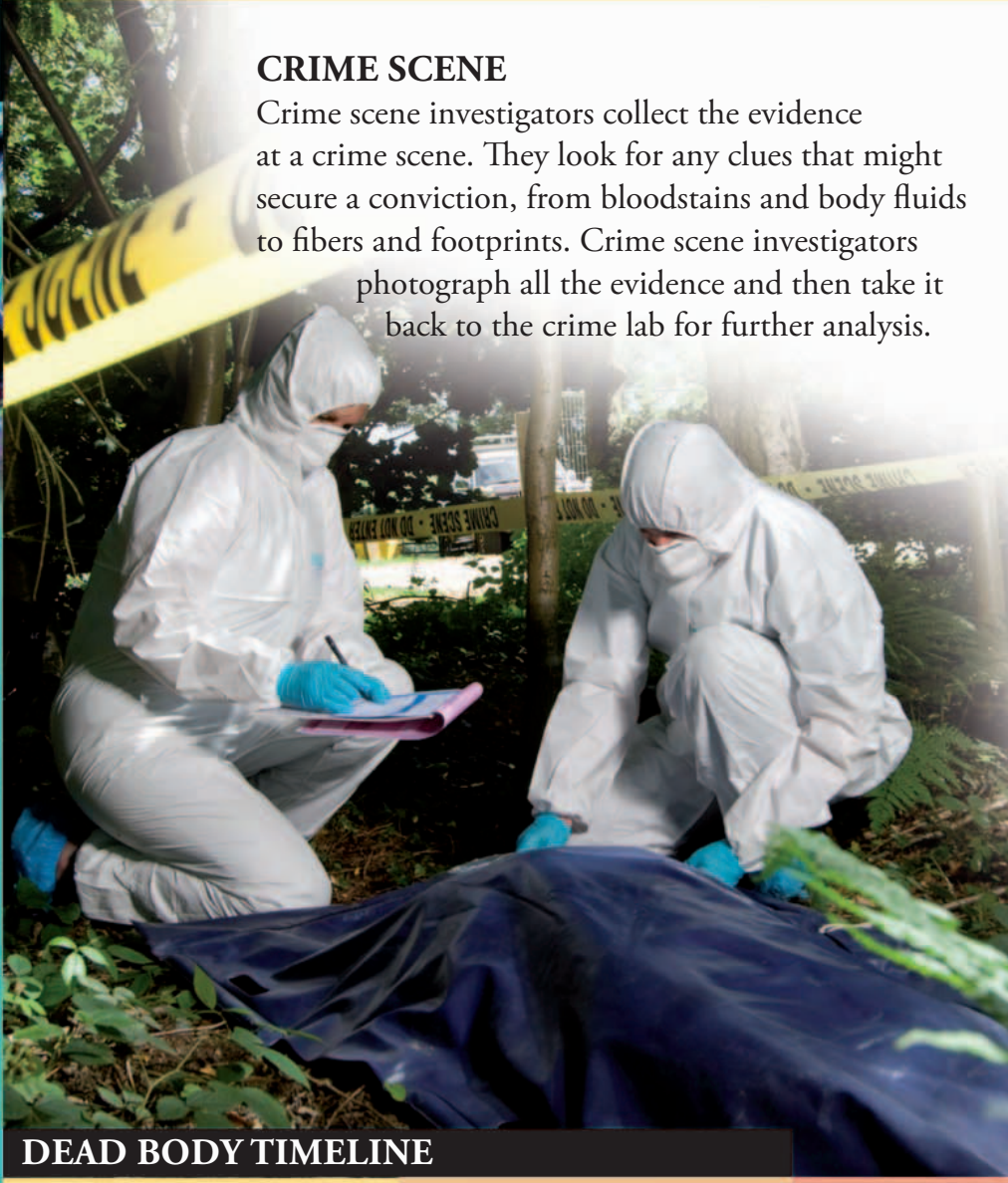
# Forensic science

Forensic science helps the police fight crime. Most people think of murder investigations when they talk about forensics, but forensic scientists deal with a range of crimes. Some are computer specialists who trace “cybercriminals” on the Internet, for example, while others are art experts who identify forgeries.

## CRIME SCENE DO NOT ENTER CRIME SCENE

### CRIME SCENE




Crime scene investigators collect the evidence at a crime scene. They look for any clues that might secure a conviction, from bloodstains and body fluids to fibers and footprints. Crime scene investigators photograph all the evidence and then take it back to the crime lab for further analysis.



**Post mortem** After any suspicious death, a doctor called a pathologist will do a post mortem. This involves cutting open the body to find out the cause and time of death. If the corpse has been dead for a long time, the time of death can be established by studying the kinds of insects present.

◀ **CRIME SCENE**  
Forensic scientists seal a body inside a body bag. The corpse will be stored at a mortuary until the post mortem.

### DEAD BODY TIMELINE

<p><b>3-36 HOURS</b></p> <p><b>Rigor mortis</b> There is a chemical change in the muscles that makes the corpse stiffen up. This starts about three hours after death and lasts about 36 hours.</p>	<p><b>0+ HOURS</b></p> <p><b>Bacterial decay</b> Bacteria start to break down the body. In warm, moist conditions, the soft, fleshy parts rot very quickly.</p> 	<p><b>0-24 HOURS</b></p> <p><b>Insect invasion</b> Insects such as flies lay eggs inside the body. When the larvae hatch, they start to feed on the rotting remains.</p> 	<p><b>50-365 DAYS</b></p> <p><b>Bare bones</b> All that is left of the dead body are the hard parts such as the skull, teeth, and bones.</p> 
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## FINGERPRINT FEATURES

If you look at your fingertips, you will notice they are covered in tiny ridges. The ridges form distinct patterns of arches, loops, and whorls. No two people have been found to have the same prints (not even identical twins) so they can be used for identification.



## DNA fingerprinting

Everyone has a unique DNA sequence (except for identical twins). Forensic scientists can turn a DNA sample into a fingerprint by breaking the DNA into small fragments and then making these spread through a sheet of gel to form a series of bands.

# DO NOT ENTER CRIME SCENE DO NOT ENTER

## Leaving prints

Criminals leave prints on everything they touch. Prints left in blood stains show up clearly. Other visible marks can be left on soft materials such as soap. Latent prints are made by natural skin oils. These prints show up when forensic scientists dust the crime scene.



Dusting brush



► **DUSTING FOR PRINTS** *A forensic scientist dusts a window to reveal a set of prints hidden on the glass.*

## Digital data

Long gone are the days of using ink to record fingerprints on paper. Instead, the police use electronic scanners to record the prints digitally. The police store the prints on a database, which can then be used to match the prints found at crime scenes. A new development is iris scanning, which looks at the colored tissue around the pupil.

▼ **IRIS SCANS** *The scanner records the features of the iris, which is unique to each person.*

► **FINGER SCAN** *A scanner records the pattern of arches, loops, and whorls that make up a fingerprint.*



## TAKE A LOOK: FACE FROM THE PAST

Forensic scientists have studied skeletal remains. They can help forensic artists to build up a 3-D image of the face from the skull. Facial reconstruction is

extremely important. It has helped the police solve crimes that happened decades ago. It also reveals what people from ancient civilizations looked like.



▲ **DEPTH MARKERS** *The artist makes a cast of the skull. Pegs act as depth markers for skin and muscles.*



▲ **FACE SCULPTURE** *The artist uses a modeling tool to build up the muscle layers with modeling clay.*



▲ **SKIN DEEP** *The artist adds a layer of clay to form the skin. The head is now fully reconstructed.*

## Cybercrime


Crime involving computers is on the increase. The crimes often involve people stealing credit-card details and pretending to be someone else. Computer experts are helping the police to track down these cybercriminals.






# TECHNOLOGY

- Technology began about 3 million years ago when people invented the first tools.
- Computers work at least a million times faster than they did in the 1940s.
- A single DVD can store as many words as over 10,000 thick books.
- There are over 600 million cars on the planet—roughly one for every 11 people.
- A space rocket makes 10 times more power at liftoff than an airplane's jet engines.

 When was the hot-air balloon invented?  
*Find out on page 254*



 What is the range of the Venturi Astrolab?  
*Find out on page 259*







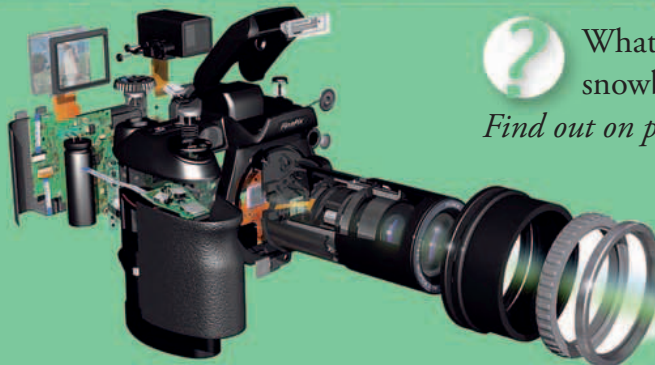
*Definition: Technology* solves practical problems to make our lives easier. It often uses science to find ways to improve things like medicines or communications.



- A vaccine for the measles has saved 7 million lives in developing countries since 1999.
- Fiber-optic cables send messages fast enough to go 5 times around the world in a second.
- Engineers have managed to fit more than 2 billion transistors on a single computer chip.
- The IBM computer firm has filed the most patents (invention ideas) for 15 years in a row.
- Over half the world's oil is used for transportation.



How does a digital camera work?  
*Find out on pages 260—261*



What is virtual snowboarding?  
*Find out on pages 264—265*





# Inventions and discoveries

Since people began living in simple dwellings, inventions have been a part of technological development. From the first use of stone for tools to the worldwide dependence on computers, people are always finding something new.

◀ **7500 BCE**  
**WHEAT AND BARLEY** *have been used to feed people for thousands of years. It is thought that it was first grown in the Middle East.*

▶ **6000 BCE**  
**DRUM** *Drums have been used for thousands of years. The remains of drums as old as 6000 BCE have been found by archeologists.*

▲ **3500 BCE**  
**BRICK** *People started making strong, waterproof bricks by baking them in a kiln instead of just letting the mud they were molded from dry in the Sun.*

▲ **3500 BCE**  
**ROAD** *One of the first roads to be built was the Persian Royal Road in 3500 BCE. It was 1,785 miles (2,857 km).*

◀ **3000 BCE**  
**COTTON** *Cotton fabrics were first made in the valley of the Indus River.*

10,000  
BCE

7500  
BCE

5000  
BCE

▲ **10,000 BCE**  
**WHISTLE** *Archeologists have found whistles dating from 10,000 BCE. The whistle may well have been the first musical instrument.*



▲ **7000 BCE**  
**FIRE** *Although fire has been used for millions of years, it was only nine thousand years ago when people discovered how to make it.*

◀ **7000 BCE**  
**CHISEL** *About nine thousand years ago people started to make stone chisels. The chisel gave the user more control when carving soft materials, such as wood.*

▲ **4000 BCE**  
**SCALES** *Early scales were beam balances. A straight length of metal or wood was held from its center, pans were hung from either end and an object was weighed in one pan against weights in the other pan.*

▲ **5000 BCE**  
**PLOW** *Seeds grow better in soil that has been prepared by a plow. Early plows were pushed or pulled by people to prepare the ground.*

▼ **3500 BC**  
**WHEEL** *Without the invention of the wheel we wouldn't be able to do lots of things today. Early wheels were made from planks of wood and were used in Mesopotamia. They were most likely to have been developed by potters who desired to make completely rounded pots.*



▲ **3500 BCE**  
**POTTER'S WHEEL** *Originally potters had to mold pots with their bare hands. With the invention of the potter's wheel pots were a lot easier to make.*





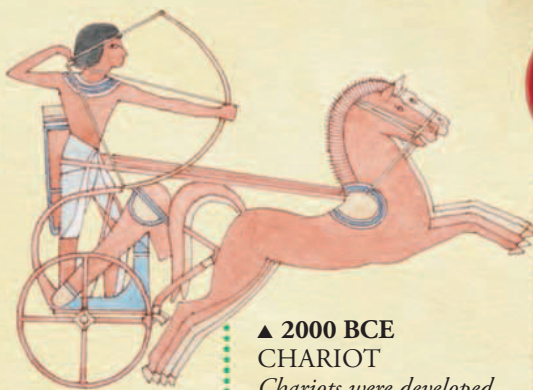
▼ 3000 BCE  
RAMP

Around 3000 BCE people started to use a mechanical aid called a ramp to help with building work. Heavy stone blocks were easier to pull up a ramp than to lift straight up.



▲ 2500 BCE  
ARCH

The first arches were built in Mesopotamia. The top of two walls were built until they met each other in the middle to form an arch.



▲ 2000 BCE  
CHARIOT

Chariots were developed from ox carts. Chariots were faster than carts, since they only had two wheels and were much lighter.



▲ 1000 BCE  
MAGNET

Magnets get their name from Magnesia, where they were first found in their mineral form (magnetite).



▲ 2500 BCE  
INK

Ink was originally made from soot and glue. It came as a dry block, it had to be mixed with water.



▼ 700 BCE  
SHADOW CLOCK

The ancient Egyptians were among the first to develop a clock. The Egyptian shadow clock had to be turned in the opposite direction halfway through the day. It had a straight scale to show hours of the day.



▲ 2900 BCE  
DAM

The earliest dam was built by the Egyptians. They built a mound to act as a dam to stop the city of Memphis from flooding.

2500  
BCE

▼ 2500 BCE  
MIRROR

Early mirrors were disks of polished bronze or copper. The first glass mirrors came nearly 4,000 years later.



2000  
BCE

▲ 2000 BCE  
LOCK

The ancient Egyptians invented locks that were made from a piece of wood and pins. Most of the locks we use today are based on the concept of the original locks.



▲ 1700 BCE  
RUNNING WATER

Minoans in Crete were the first to build drains and pipes so they could have running water in the palace of Knossos.

◀ 3000 BCE  
CANDLE

Candlesticks dating from 3000 BCE have been found in Egypt and Crete. Candles are made from putting thin cords in liquid wax.



▲ 2500 BCE  
WELDING

Welding was first used to join pieces of metal together to make jewelry.



◀ 900 BCE  
ALPHABET WITH VOWELS AND CONSONANTS

The Greeks adapted the ancient Palestinian alphabet (with symbols for consonants) and made their own, which included vowels and consonants.

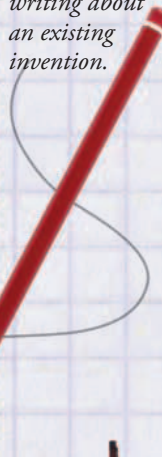


The golden age of invention and discovery came in the last two hundred years. New scientific theories helped people invent things that changed the world.



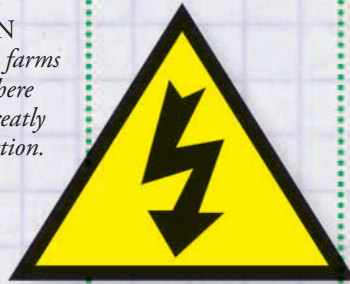
▲ 1280  
EYEGASSES  
English scientist Roger Bacon came up with the idea of using a magnifying glass as a reading aid. In 1301, two Italian inventors took it a step further by inventing eyeglasses.

▼ 1565  
PENCIL  
Conrad Gesner of Switzerland is credited with inventing the pencil, but may only have been writing about an existing invention.

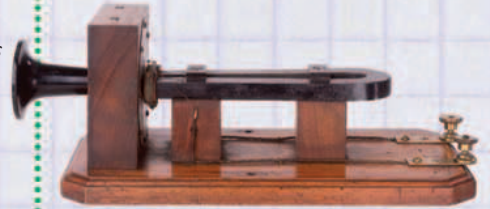


▲ 1700s  
INDUSTRIAL REVOLUTION  
Jobs moved from farms into factories, where new machines greatly increased production.

▼ 1800  
ELECTRICITY  
The Italian scientists Luigi Galvani and Alessandro Volta invented the first device to give a continuous flow of electricity.



▼ 1876  
TELEPHONE  
Alexander Graham Bell holds the patent for the telephone. He was the first to make it successful, but there is evidence that others, such as Antonio Muecci, invented it first.

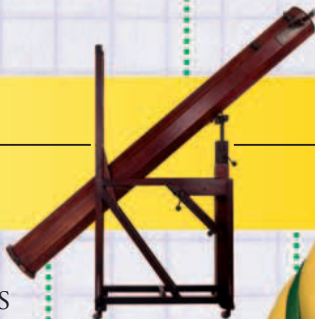


◀ 1878  
LIGHTBULB  
Thomas Edison and Joseph Swan came up with the idea of the electric lightbulb independently. No need for candles and gas lamps—life would be much easier for everyone.

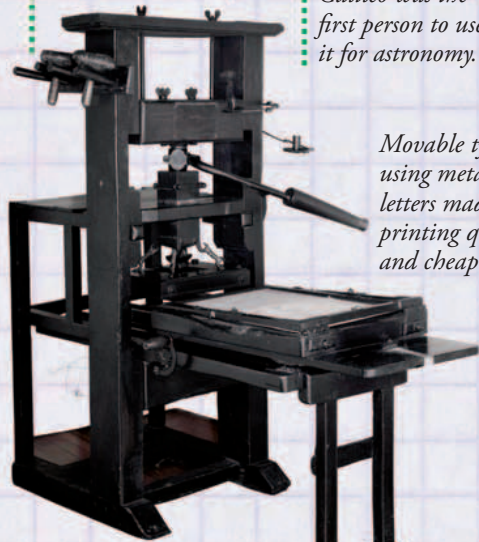


1500  
CE

1800  
CE



▼ 1455  
PRINTING PRESS  
Johannes Gutenberg's invention allowed multiple copies of books to be printed, making them available for everyone to read.



▲ 1608  
TELESCOPE  
Hans Lippershey is generally credited with inventing the first telescope, but Galileo was the first person to use it for astronomy.

Movable type using metal letters made printing quick and cheap.



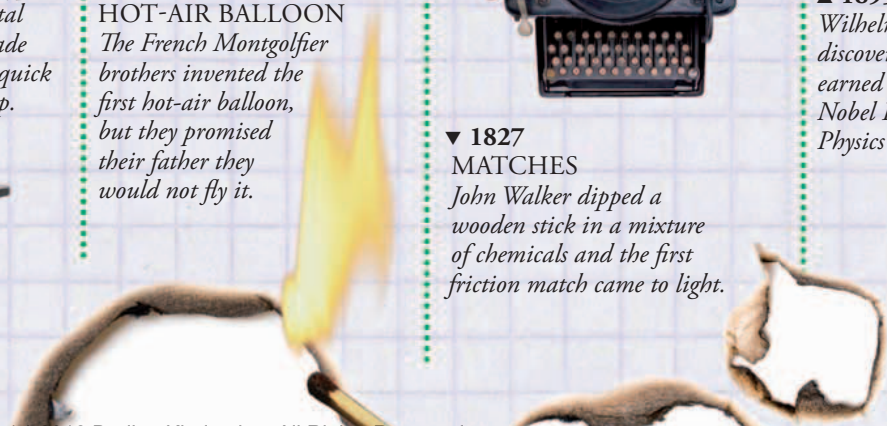
▲ 1783  
HOT-AIR BALLOON  
The French Montgolfier brothers invented the first hot-air balloon, but they promised their father they would not fly it.

▼ 1868 TYPEWRITER  
Christopher Scholes and partners patented the typewriter. The American company Remington and Sons took their invention into production in 1873.



▲ 1895 X-RAY  
Wilhelm Röntgen's discovery of X-rays earned him the first Nobel Prize for Physics in 1901.

▼ 1827  
MATCHES  
John Walker dipped a wooden stick in a mixture of chemicals and the first friction match came to light.







▲ **1903**  
**POWERED FLIGHT**  
*The pioneers of powered flight were Orville and Wilbur Wright, who took to the skies in a plane known as the Wright Flyer. Their historic flight over the sands of Kitty Hawk in North Carolina, lasted only 12 seconds.*

▼ **1928**  
**SLICED BREAD**  
*When Otto Rohwedder invented a bread slicer, many bakers thought the idea was silly because the bread would go stale. Little did they know!*



▲ **1977**  
**PERSONAL COMPUTERS**  
*Our lives have been transformed by PCs. Almost every office, school, and home in the developed world now includes PCs for everyone to use.*

▼ **1979**  
**CELL PHONE**  
*The first commercial cell phone was about the same size as a brick. It was developed and launched in Japan, but the idea had been around for more than 20 years.*



◀ **1982**  
**CD**  
*The first compact discs hit the stores in 1982. They have continued to be a popular way of storing data in digital form.*



▲ **1983**  
**INTERNET**  
*The Internet grew out of a network of computers that linked universities and the military across the United States. Today, it is used for the World Wide Web, email, and much more.*



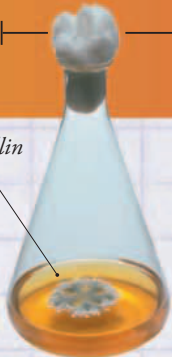
▶ **2001**  
**MP3 PLAYERS**  
*Apple launched its first portable MP3 player, called the iPod. Within two years, they were becoming integrated with cell phones.*

▲ **2005**  
**E-READER**  
*E-books, which are read on e-readers, are the digital equivalent of printed books. They are popular in Japan.*

1900  
 CE

2000  
 CE

Penicillin mold



▲ **1928**  
**ANTIBIOTICS**  
*Sir Alexander Fleming discovered penicillin, but left it to others to turn it into a practical treatment that saved millions of lives.*

▼ **1957**  
**FIRST SPACE SATELLITE**  
*The Soviet Union launched the first artificial satellite, Sputnik 1, on October 14. Within a month, they had launched a dog named Laika into space aboard Sputnik 2.*



◀ **1938**  
**BALLPOINT PEN**  
*A Hungarian named Laszlo Biro invented the ballpoint pen, but World War II put back production until 1943.*



**1980**  
**POST-IT NOTES**  
*Dr. Spencer Silver discovered a repositionable glue in 1968—but had no use for it. In 1974, his colleague Art Fry used it to stop his bookmark from falling out. From this, the Post-it note was created.*



▲ **1982**  
**FIRST ARTIFICIAL HEART**  
*A dentist from Seattle became the first person to be implanted with an artificial heart.*

▶ **1997**  
**DOLLY THE SHEEP**  
*Scientists at the Roslin Institute in Scotland cloned the first mammal and named her after country and western singer Dolly Parton.*



**FAST FACTS**

- German-born U.S. scientist Albert Einstein started his career studying new inventions in a patent office in Switzerland.
- The first electric washing machine was invented by U.S. engineer Alva Fisher in 1907.
- Thomas Edison is credited with more than 1,000 new inventions during his life and is one of the most successful inventors of all time.



**SLICE OF SURGERY**

The image of a surgeon has changed from backstreet doctors to computer-controlled robots such as the da Vinci Surgical System, which can perform routine surgical procedures with precision.



▲ **THROUGH THE KEYHOLE** *Surgeons use an endoscope to look inside a patient's body.*



▲ **PLASTIC FANTASTIC** *Skin grafting is one of the most common procedures in plastic surgery.*



▲ **HEART SURGERY** *is now routine thanks to advances in technology.*

# Modern medicine

Medicine has come a long way since the Greek philosopher Hippocrates laid the foundations for modern medicine nearly 2,500 years ago. Advances in all areas of medicine are now helping us live longer, healthier, and happier lives.

**MEDICINE IN MINIATURE**

Making things smaller allows doctors to see and do more. In the future, nanotechnology could revolutionize medicine, with developments such as nanorobots.



◀ **SEEING INSIDE THE BODY**  
*A man swallows a capsule endoscope. As the capsule passes through the body, it relays images of the man's insides to a video screen so doctors can study them.*

White blood cell

**Nanorobotic surgeons**

Miniature devices called nanorobots could be used to help surgeons repair the body from the inside out. The nanorobots could circulate in our blood and attack harmful germs.



Red blood cell

Nanorobot

**MEDICINE THROUGH TIME**

**6,500 BCE**

• Trepanation was a form of primitive surgery that involved drilling holes in the skull to release "evil spirits."



**1590 CE**

• Dutch father and son Hans and Zacharius Jannsen invent the first microscope, and by doing so open up the invisible world of the cell.

**1867 CE**

• Sterilization practices pioneered by Joseph Lister.

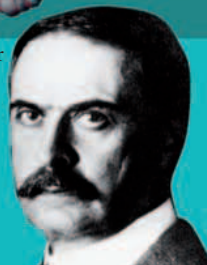


**1895 CE**

• X-rays are discovered by Wilhelm Röntgen and later used to look inside the body without the need for invasive surgery.

**1901 CE**

• Karl Landsteiner discovers the ABO human blood group system.

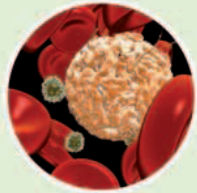
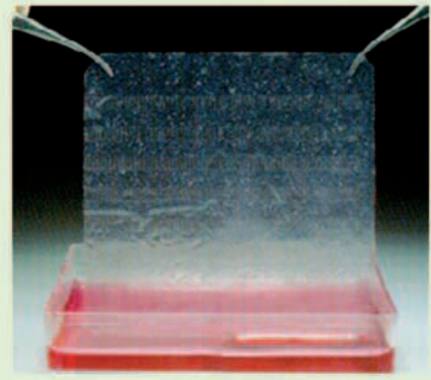
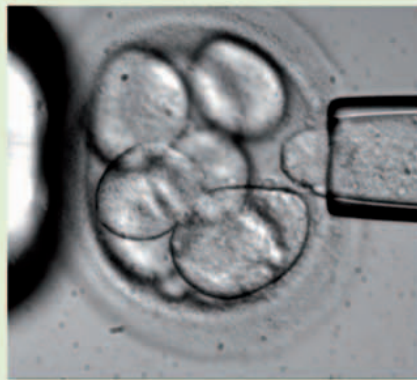






TAKE A LOOK: STEM CELLS

It is now possible to grow new tissues and organs from stem cells rather than wait for transplants. Stem cells are primitive cells that can divide and produce any type of cell in the body. The body will not reject tissues and organs grown from stem cells because they come from the patient's own body.



▲ **STEM CELL**  
*Doctors use stem cells taken from the body.*

▲ **EMBRYONIC STEM CELLS**  
*In the laboratory, scientists isolate the stem cells from a developing embryo.*

▲ **SKIN FROM STEM CELLS**  
*The stem cells are used to generate new skin for use in transplant surgery.*

BODY REBUILDING

When the body cannot repair itself, doctors use technology to rebuild it. Advances include miniature retinal implants that can restore sight and prosthetic limbs under direct control of the brain.



▲ **SPRINT CHAMP**  
*South African Oscar Pistorius is a sprinting champion with spring-loaded legs.*

► **MIND CONTROL**  
*Former US marine Claudia Mitchell uses her brain to move her prosthetic arm.*



WHO'S WHO?

- **Hippocrates** (c. 460–c. 377 BCE) becomes the founding father of modern medicine. Hippocrates suggests that disease has natural causes rather than being a punishment from the gods.
- **William Harvey** (1578–1657) studies the circulatory system and shows how the heart pumps blood around the body.
- **Elizabeth Blackwell** (1821–1910) becomes the first woman to graduate with a medical degree from Geneva College in New York in 1849.
- **Dr. Crawford Long** (1815–1878) uses ether as an anesthetic during surgery.
- **Sir Alexander Fleming** (1881–1955) discovers penicillin. In 1940, Howard Walter Florey (1898–1968) and Ernst Chain (1906–1979) mass-produce penicillin as an antibiotic.
- **John Heysham Gibbon Jr.** (1903–1973) invents the first heart-lung machine in 1935. He performs the first open-heart surgery on a human in 1953.
- **Christiaan Barnard** (1922–2001) a South African surgeon, performs the first successful heart transplant in 1967.

1950 CE

Surgeons from Chicago perform the first successful organ transplant—the kidney of a woman named Ruth Tucker.

1957 CE

The first practical transistorized pacemaker was made by Earl Bakken.



1985 CE

For the first time, surgeons use a robotic assistant called PUMA 560 to help take a tissue sample from the brain.

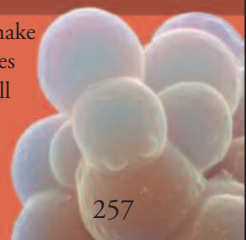
1996 CE

Scientists clone the first mammal—Dolly the Sheep (died 2003).



2007 CE

Doctors make huge strides in stem cell research.





# Electric cars

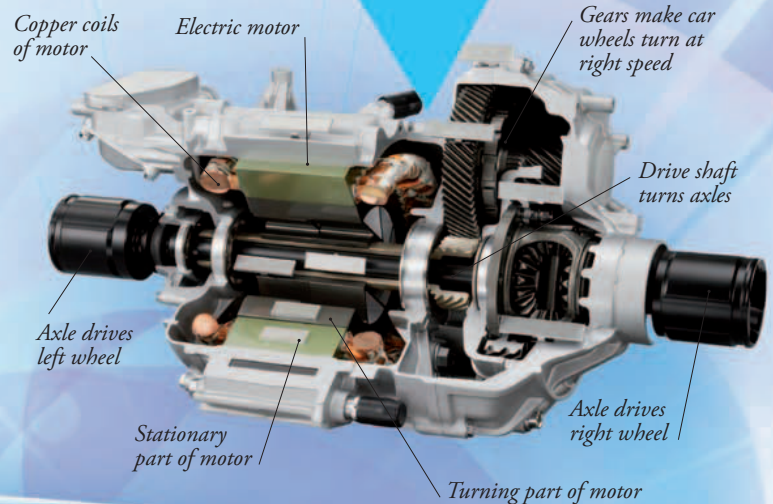
Most cars use gasoline, made from oil, which causes pollution and adds to global warming. Oil supplies are running out, too. That's why car designers are turning to electric engines, which can use energy from cleaner sources.

## HONDA FCX CLARITY

This might look like an ordinary car but it's powered in what could be a much cleaner way. In a normal car, the engine burns gasoline, releases energy, and makes pollution. But in this car the fuel tank is replaced by a kind of battery called a hydrogen fuel cell. This takes hydrogen from a tank and oxygen from the air, reacts them together, and produces electricity. The only waste product is steam, so if the hydrogen comes from a clean source there is no pollution at all.



▲ Open the hood of an electric car and you won't find a gas engine. Instead, there's an electric motor (shown below in a cutaway).



### TAKE A LOOK: HOW IT WORKS

- 1 The hydrogen tank stores enough fuel to power the car for 280 miles (450 km).
- 2 The fuel cell chemically reacts hydrogen from the tank with oxygen from the air to make electricity.
- 3 The rechargeable battery stores energy released when the car brakes and helps the fuel cell power the car.
- 4 The power drive unit works like a gearbox. It makes more electricity flow from the battery to the motor.
- 5 The electric motor is light and compact and turns the front wheels to drive the car along.





## Suzuki pixy

*Three-wheeled, low-speed city car*

- **Top speed** Less than 20 mph (30 km/h)
- **Range** 20 miles (30 km)
- **Made in** Japan

Suzuki has created a single-seater electric pod that is great for short journeys. Two of the Pixy pods can sit in a fuel-cell coach that recharges them as it moves. The larger coach can go on longer journeys.



## Microcab

*Useful for short journeys*

- **Top speed** 40 mph (64 km/h)
- **Range** 50–100 miles (80–160 km)
- **Made in** United Kingdom

Fuel cell cars are being used as taxis in Birmingham, England. They are incredibly light and can travel for 100 miles (160 km) before they need to stop and refuel.



## The life car

*Stylish and speedy fuel-cell sports car*

- **Top speed** 85 mph (140 km/h)
- **Range** 200 miles (320 km)
- **Made in** United Kingdom

Built from lightweight aluminum, this Morgan uses five times less energy than an ordinary steel-bodied car. It speeds from 0 to 60 mph (0 to 100 km/h) in 7 seconds!



## Venturi Astrolab

*High-performance car powered by sunlight*

- **Top speed** 75 mph (120 km/h)
- **Range** 60 miles (110 km)
- **Made in** France

This solar car has no engine or fuel cell. Instead, it's covered in solar panels with lenses on top. These capture sunlight, turn it into electricity, and store it in batteries.



# WOW!

Few electric cars are 100 percent eco-friendly, because their batteries have to be charged using electricity. Most electricity still comes from power plants burning dirty fuels. These make pollution and add to global warming.

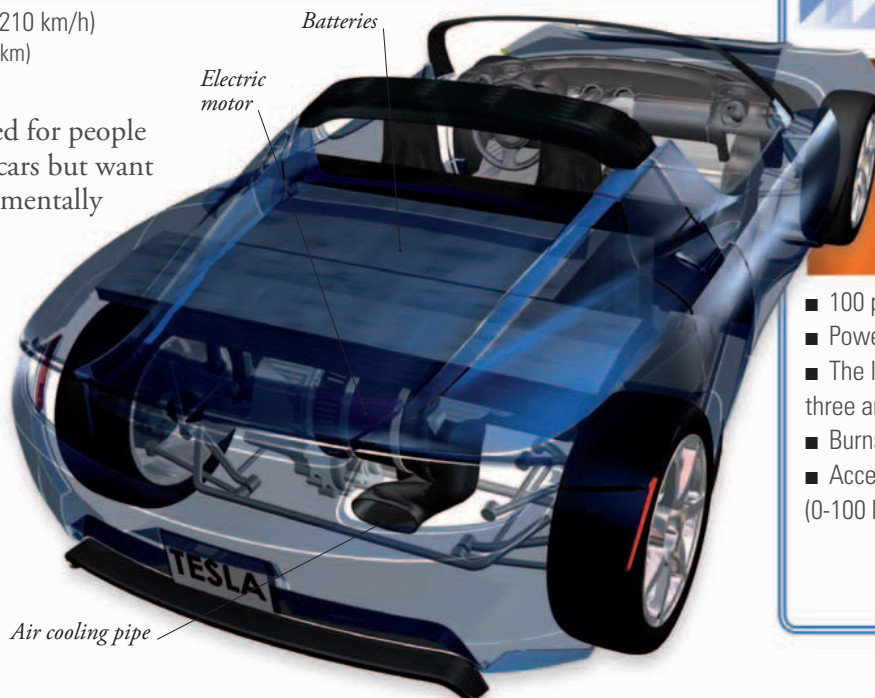
## Tesla roadster

*Fast, quiet, and less polluting*

- **Top speed** 130 mph (210 km/h)
- **Range** 250 miles (400 km)
- **Made in** US

The Tesla is designed for people who love ordinary cars but want them to be environmentally friendly as well. Its powerful electric motor can accelerate almost as fast as a gas-driven Ferrari!

▶ **TESLA ROADSTER**  
The Tesla's rear wheels are powered by an electric motor and batteries at the back.



### TESLA ROADSTER



- 100 percent electric.
- Powered by 6831 laptop batteries.
- The lithium-ion battery pack takes three and a half hours to charge.
- Burns no oil.
- Accelerates from 0–60 mph (0–100 km/h) in only 4 seconds.



# Through a lens

Cameras are everywhere. Cell phones often include them, they are used in security systems, in space exploration, medical equipment, and in speed cameras. Cameras are devices that capture still or moving images.

► **MEMORY CARDS** can store thousands of digital images.



## GOING DIGITAL

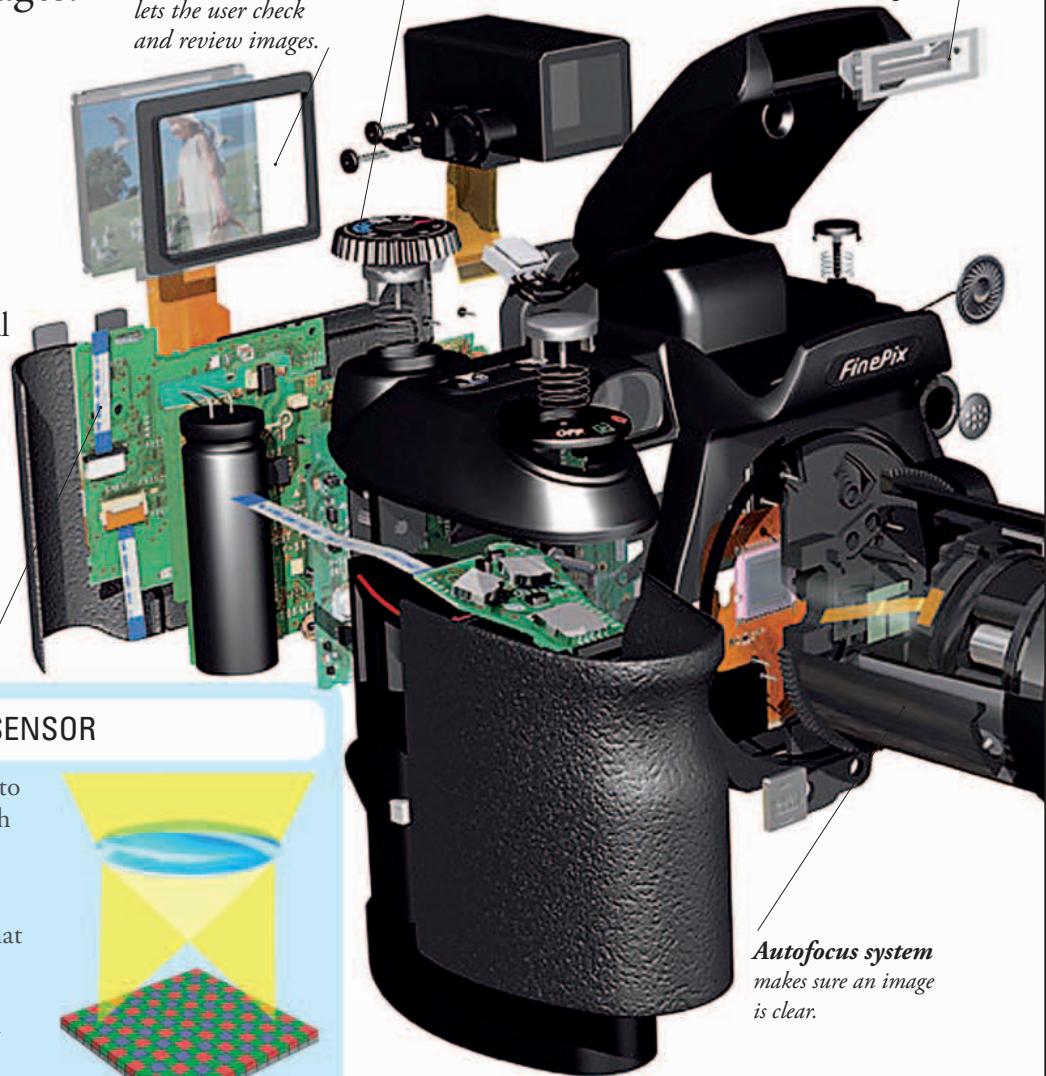
Digital cameras are similar to film cameras except that they store the images on a memory card. Their lenses focus the image onto an electronic sensor (CCD or CMOS) that converts the light into electrical charges. The charges are measured to give digital values. Computer chips process the data to construct the image, which is then stored on a memory card.

*A circuit board processes information from the sensor into a digital format.*

*The digital screen lets the user check and review images.*

*A control dial allows the photographer to have control over settings.*

*An inbuilt flash provides light when it is too dark to take a photo.*



*Autofocus system makes sure an image is clear.*

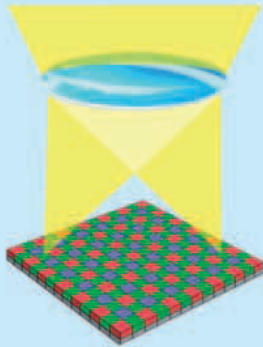


## TAKE A LOOK: SENSOR

A digital camera requires a sensor in order to work. A shutter allows light to pass through the lens to a sensor. The sensor is a grid of millions of pixels.

Each pixel measures the amount of light that hits it through a green, blue, or red filter.

The measurements are changed into digital information that is used to make the final digital image.



## TIMELINE OF CAMERAS

### Tenth century

The concept of a camera obscura is credited to Abu Ali Al-Hasan. It works by light passing through a hole and hitting a surface, where it forms an upside-down image. In later models mirrors were used to reflect the image so that it appeared the right way up.

### 1500s–1800s

Artists used more developed camera obscuras to trace images of scenes onto paper. The invention of the camera obscura led to the development of modern-day cameras.

### 1840s

Simple photographic cameras were in use by the 1840s and were little more than a wooden box with a hole cut to hold a lens. Images were recorded on a glass or metal plate.

### 1880s

Photographic film was made in the 1880s. It was made from a strip of plastic coated with crystals of a silver compound. Cameras were developed to include an automatic shutter mechanism allowing the right amount of light in the lens.





## FACT FILE

**Movie cameras** are similar to still-image cameras except that the film runs continually. Each frame of film captures a slightly different image so that when the frames are run back through a projector you get the illusion of continuous movement. Movie cameras can also record sound at the same time.



**Professional studio cameras** are used in television. They split the light into red, green, and blue and detect each color separately, which gives a better quality image. The pictures are sent to a separate recorder. Most studio cameras are mounted on special carts, but they can also be attached to moving vehicles.



**Video cameras and camcorders** These initially used analogue and then digital tape to record and store information. Now they use optical disks or memory cards. Camcorders are mainly used for home movies. Over the years they have become smaller and lighter and can be carried in one hand.



▼ **INSTANT PRINTS**

*Polaroid cameras take pictures that develop themselves, producing a photo a minute or so after it has been taken.*



*Lenses can be changed over to obtain a required effect. Wide angle lenses, as the name suggests, are used to take wide shots.*

*Filters control the light coming through the lens.*

*Light needs to travel through the lens in order to capture an image.*

# WOW!

The first CCTV (closed-circuit television) camera that was installed in the UK was in 1949. It was put in Guy's Hospital, London, United Kingdom. There are approximately 20 million CCTV cameras in the world.



**1920s**  
Small cameras with interchangeable lenses were developed in the 1920s. This allowed photographers to take a wider range of photographs.

**1970s**  
Cameras were made with automatic exposure and electronic autofocus in the 1970s.

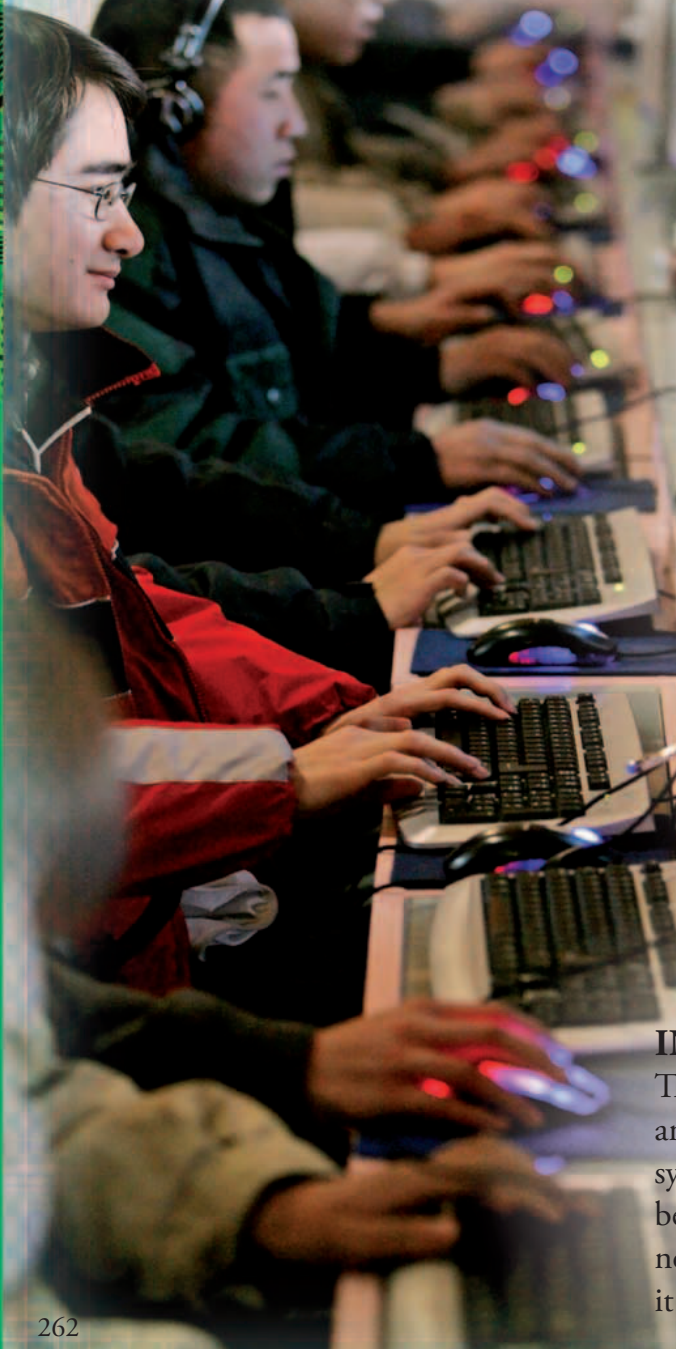
**1990s**  
The technology for digital cameras was invented in the 1970s and it was developed in the 1980s, but it wasn't until the 1990s that digital cameras came into popular use.





# Global village

Technology is helping to bring our planet together. People on the other side of the world live up to 12,500 miles (20,000 km) away, but you can email or phone them in seconds. Hundreds of millions of computers in more than 200 countries are now connected into a giant network called the Internet.



## INTERNET

The Internet is the name for the telephone, satellite, and cable connections that link the world's computer systems. In theory, every computer in the world can be indirectly connected to every other one. There is no central control system for the Internet. This means it can survive major failures very easily.



## ELECTRONIC MAIL

Electronic mail (email) is a way of sending written messages between computers. Invented in 1971, it has now become one of the world's favorite forms of communication—especially for work. No one really knows, but it's thought that somewhere between 100 and 500 billion emails are sent worldwide each day.



**WOW!**

The World Wide Web is like a huge library you can use over the Internet. It has around 200 million separate websites containing well over 20 billion text pages, photographs, and music and sound files.

## CELL PHONES

Ordinary phones are fixed in place because they have to be connected with wires. Cell phones can go anywhere because they send signals with radio waves. There are more than three billion cell phones in the world. They've proved to be a big hit in developing countries, where traditional telephone networks cost too much to build.

## NEWS

When letters were the fastest way to communicate, it could take months for news to go around the world. Now, with satellite and Internet technology, you can watch events happening live. Using a website, you can even set up your own personal newspaper, called a blog.

## BRINGING PEOPLE TOGETHER

The Internet has created new ways for people to connect. Social networking websites, where people make friends and share interests, are very popular. A website called Facebook has over 150 million members worldwide. If it were a country, it would be one of the ten biggest nations on Earth.



# Is this real?

Virtual reality (VR) uses computers to create the illusion of being in a completely different environment. VR stimulates the senses with artificial sights and sounds, tricking the brain into thinking the experience is real.

**WOW!**

VR systems allow users to see virtual objects, but some enable a sense of touch, too. A user wears a special pair of gloves with small inflatable bladders inside them that allow the person to actually feel virtual objects.



◀ **INTERACT**  
*A woman wears VR glasses and uses a wand to interact with a virtual world.*

## HAVING FUN WITH VR

In most VR systems, headsets or glasses project the image of the virtual world in front of the user's eyes.

People interact with the virtual world using devices such as joysticks, tracking balls, control wands, voice-recognition software, data gloves, and treadmills.

▲ **VR GAMES**  
*Virtual reality recreates the sensation of snowboarding.*

## VIRTUSPHERE

The "VirtuSphere" is a ball that moves on rollers, so the user can walk on an unlimited amount of space.

The user wears a wireless headset to track movement and create a picture of the virtual world.

◀ **USING VR** *The VirtuSphere has many uses, ranging from military training to virtual tours of museums.*

## INDUSTRIAL DESIGN

Architects, manufacturers, and designers use VR to test new products or building designs. Testing in the virtual world eliminates any problems before actual work is performed.

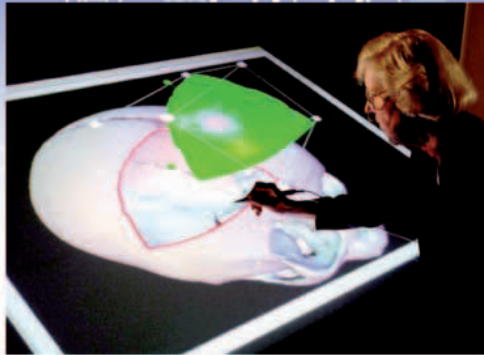
▶ **WALK IN THE PARK**  
*An architect uses VR to look at a proposed design for a new park.*





## TRAINING DOCTORS AND SOLDIERS

The military uses virtual reality to simulate dangerous battle scenes without putting the lives of any soldiers at risk. And in hospitals, trainee surgeons practice virtual surgery on computer screens without harming live patients.



▲ VIRTUAL SURGERY *A surgeon views a VR image of a patient's head prior to surgery.*



▲ WAR GAMES *A soldier fights on the virtual battlefield to train for real combat.*



## FLIGHT SIMULATION

Pilots train in flight simulators—one of the earliest forms of virtual reality. The pilot sits inside a life-size replica of a cockpit and views computer-generated images of the outside world. The controls of the simulator respond in the same way as those of a real aircraft.

◀ FLIGHT SIMULATOR  
*Using VR, a pilot can learn to fly without putting lives in danger.*

## SPACE EXPLORATION

The American space agency NASA used virtual reality to help with the design of a Mars rover vehicle before it sent the latest rovers, *Spirit* and *Opportunity*, to the surface of Mars. Astronauts also use VR to prepare for space missions.



◀ MARS ROVER *An engineer uses virtual reality to help understand the problems of navigation on the rocky surface of the red planet.*





# Robotics

Robots are machines that can do the kind of jobs that people do but never get tired or bored. Some robots work in dangerous places. Others have artificial intelligence, making them smart enough to solve problems and learn from experience.

## ROBOTIC SURGERY

Surgeons use robots to do operations that would be too difficult for human control. They study the operation site on a TV screen and guide the robot by remote control.



◀ DA VINCI is a surgical robot used to perform complex surgical procedures.

**WOW!**

In 2001, surgeons used robotic surgery to remove a patient's gall bladder. The surgeons were based in the United States, but the robot and patient were in France.

## Space exploration

- **Name** Mars Exploration Rover
- **Cost** \$820 million

In 2003, NASA deployed two robotic vehicles called rovers to explore the surface of Mars. The robots work in conditions that are far too difficult for human astronauts.



## Spy plane

- **Name** MQ-1 Predator Drone
- **Cost** \$4 million

The Predator Drone is an unpiloted aerial vehicle used for surveillance. It is controlled, via a satellite link, by a pilot on the ground and is equipped with two Hellfire missiles.



## Bomb disposal

- **Name** Remotec HD-1
- **Cost** Around \$110,000

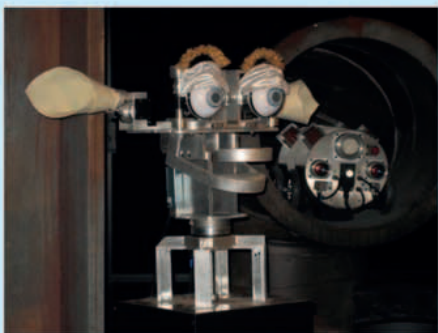
This robotic bomb disposal unit is equipped with a color camera and a telescopic arm and pincer to disarm explosive devices such as land mines without risking lives.



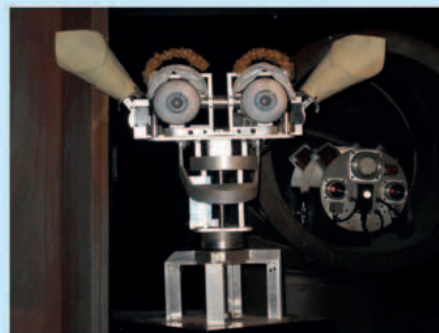
## TAKE A LOOK: FACIAL EXPRESSIONS

Engineers at the Massachusetts Institute of Technology in the United States developed a robot called Kismet.

The robot copies human expressions by moving parts of its "face" and can learn by talking and interacting with people.



▲ **HAPPY** Kismet can simulate human emotions such as happiness by copying the smiles of people it talks to.



▲ **SURPRISE** The robot can learn from experience but will appear "surprised" in unusual situations.



## Industrial robots

- **First used** 1960s
- **Cost** Varies according to use

Industrial robots such as those used in car assembly lines are computer-controlled machines that do the same jobs over and over again. They are fast and accurate and do not get tired like human workers do.



## Domestic robots

- **Name** Robomow
- **Cost** About \$1,600

Some robots are designed to take the hard work out of domestic chores such as mowing the lawn. Robomow is a robotic lawn mower that uses sensors to avoid trees and other hazards in its path.



### TELL ME MORE...

The Roomba robotic vacuum cleaner was introduced by the US company iRobot in 2002. It works by sensing obstacles such as furniture and walls and avoiding them.

## ROBOTIC ANIMALS

In the 2000s, Sony developed a robotic dog called AIBO, shown above playing soccer in the 2004 RoboCup soccer event. AIBO is a complex robot that can see and hear and has a sense of balance and touch. The robot moves and behaves almost like a real dog, for example, by chasing a ball. Sony no longer makes AIBO because the company did not sell enough to make a profit.



# Nanotechnology

▼ **MICROMECHANICS** Scientists have already made machine parts on the scale of micrometers (millionths of a meter). The parts are shown below next to a fly's leg to show how small they are.



Fly's leg

The word *nanotechnology* describes the development of devices on the scale of atoms. Scientists hope to use this new technology to produce some amazing inventions, from nanorobots used in surgery to nanomaterials that could take people to the Moon.

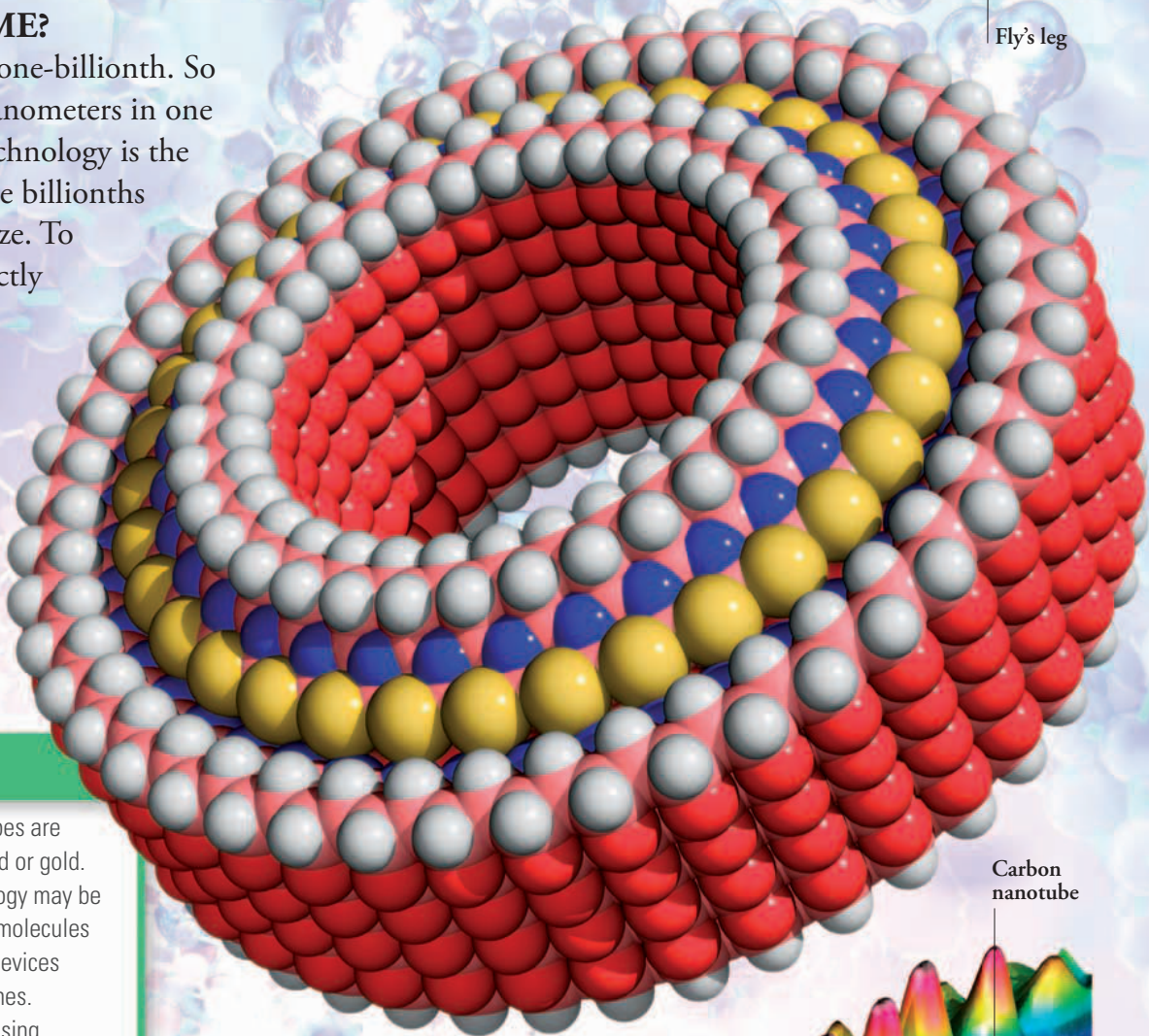
## WHAT'S IN A NAME?

The word *nano* means one-billionth. So there are one billion nanometers in one meter (3 feet). Nanotechnology is the study of devices that are billionths of a meter (3 feet) in size. To give you an idea of exactly how small that is, one nanometer would be 100,000 times smaller than the width of a human hair.

► **ROTATING PARTS**  
*Individual carbon and hydrogen atoms arranged in a circle could form the bearings for rotating parts in a nanomachine.*

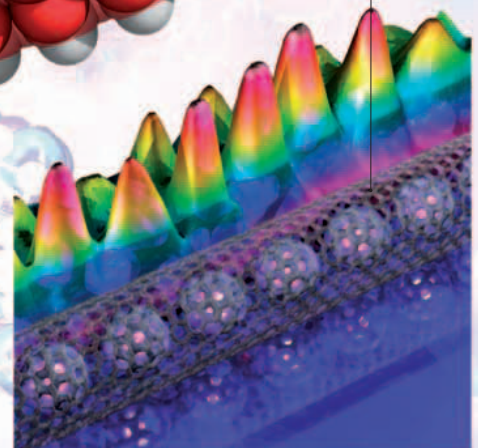
## NANO FACTS

- By weight, carbon nanotubes are more expensive than diamond or gold.
- In the future, nanotechnology may be used to assemble individual molecules into the parts for electronic devices such as laptops and cell phones.
- Other electronic devices using nanosized parts include flexible digital screens and sensors that may detect chemicals in the air.
- Scientists hope to build nanosensors to weigh molecules as small and as light as a strand of deoxyribonucleic acid (DNA).
- Nanotechnology is being used to make "smart drugs" that target individual cancer cells and kill specific germs.



Carbon nanotube

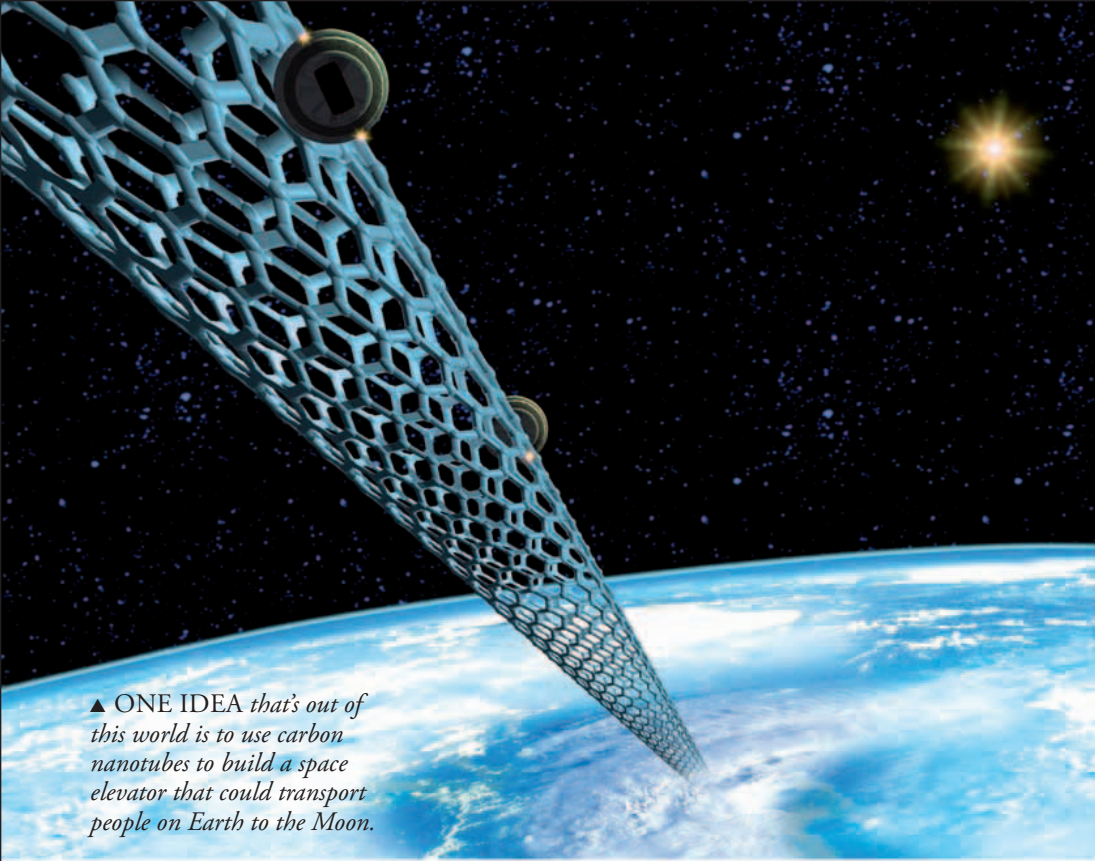
**Nanomaterials** Scientists are getting very excited about structures called carbon nanotubes. These tiny tubes of carbon atoms are stronger than diamond and extremely long compared with their width. They are better conductors of electricity than metal, which makes them ideal for future electronics.





# WOW!

Scientists are looking at the possibility of using **strong nanomaterials** to build very tall skyscrapers. Carbon nanotubes are one possibility. The carbon atoms in these tiny tubes form hexagon shapes, making them extremely strong and lightweight. Engineers could use the carbon nanotubes as the supporting structures for the skyscrapers.



▲ ONE IDEA that's out of this world is to use carbon nanotubes to build a space elevator that could transport people on Earth to the Moon.

## NANOTECHNOLOGY IN ACTION

Scientists have already made tiny electric motors, gears, and springs that are just a few hundred nanometers across. In the future, they hope to connect these miniature parts to make nanomachines and nanorobots. These devices could be used to help surgeons repair the human body from the inside or they could circulate in our blood and attack harmful germs.

► A ROBOT FLY is similar in size to a real fly, but the electronic components inside the robot fly are nanometers across.



**Everyday nanotechnology** While the future uses of nanotechnology may lie with hi-tech industries such as electronics and robotics, this emerging technology has already found uses in many everyday items, ranging from clothing and paints to cosmetics and health-care products.



◀ NANOPARTICLES in sunscreen ensure even coverage and do not leave white marks on the skin.

**Robotic ants** Scientists are using microrobotic ants to study the behavior of real ants. Nanotechnology helps in the manufacture of the tiny electronic circuits that control the movement of the robots.



◀ A WATER-REPELLENT fabric is covered with a layer of nanoparticles. The water forms a near-perfect sphere as it touches the waterproof layer and rolls away from the fabric. The droplets collect dirt as they roll over the surface and so they clean the fabric, too.



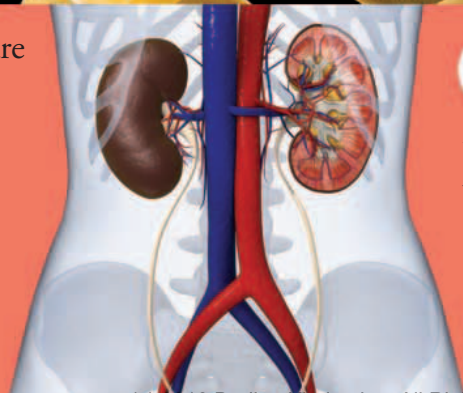
# THE HUMAN BODY

- At rest, a child's heart beats about 85 times a minute.
- The left lung is slightly smaller than the right lung.
- A human being takes about 23,000 breaths each day.
- There are about three million pain sensors in a human body. Most are in the skin.
- Your ears will grow about  $\frac{1}{4}$  in (6.55 mm) in 30 years.



Which **organs** are these?

*Find out on page 287*

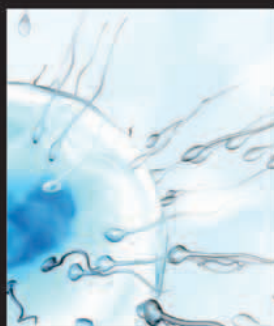
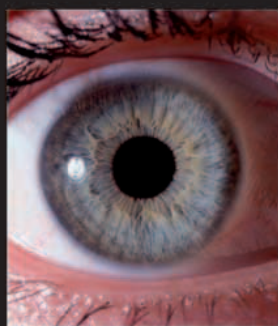
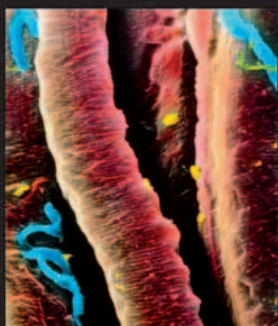


How fast do **nerve impulses** travel?

*Find out on page 281*









*Definition:* The **human body** is an amazing machine. Humans are mammals who breathe air and eat plants and animals to nourish their bodies and provide energy.

- You blink more than 9,000 times a day.
- In most places, your skin is about  $\frac{1}{16}$  in (2 mm) thick.
- In a fingernail-sized patch of skin, there can be up to 600 sweat glands.
- On average, a human body contains enough iron to make a nail 1 in (2.5 cm) long.
- A drop of blood contains around 5 million red blood cells.

 How many **nerve cells** are in a human brain?  
*Find out on pages 280–281*



 How many **bones** are in an adult human skeleton?  
*Find out on page 274*





# Your body

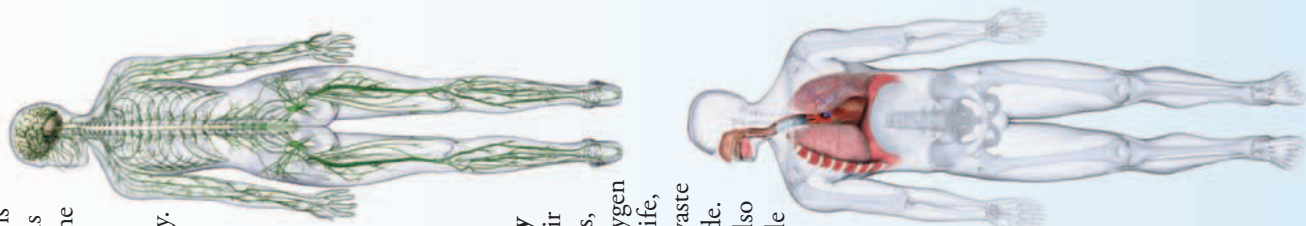
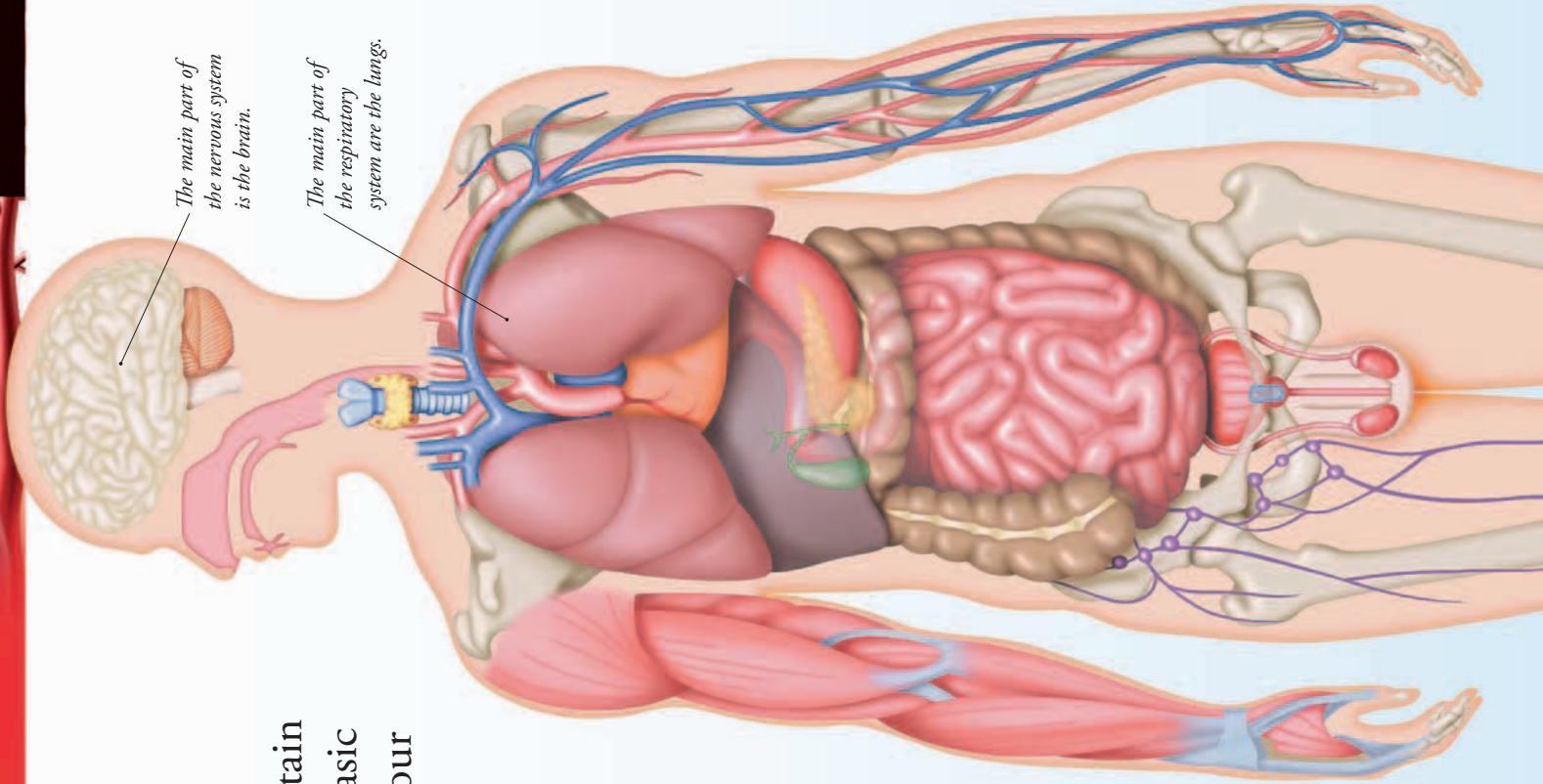
Six billion human beings share planet Earth. Each is unique. We all share certain characteristics, however, notably our basic body systems, from our circulatory to our respiratory system. Body systems are made up of groups of tissues and organs that work together.

**The nervous system** is composed of the brain, the spinal cord, nerves, and sense organs. This is what controls everything the body does, much of it automatically.

The main part of the nervous system is the brain.

The main part of the respiratory system are the lungs.

**The respiratory tract** draws air into the lungs, extracting oxygen required for life, then expels waste carbon dioxide. The system also enables people to speak.

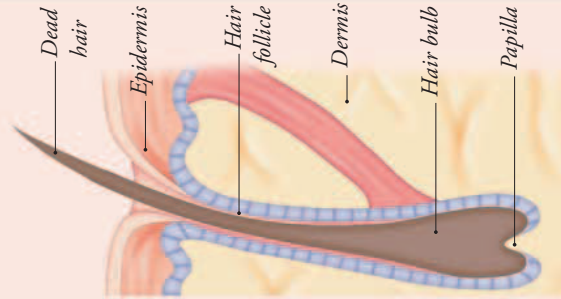


## SKIN, HAIR, AND NAILS

Our skin, hair, and nails form a protective covering and together form a body system called the integumentary system. Your hair and nails grow through your skin, which is the body's largest organ. Dead skin cells are constantly shed from the surface of the skin.

### FAST FACTS

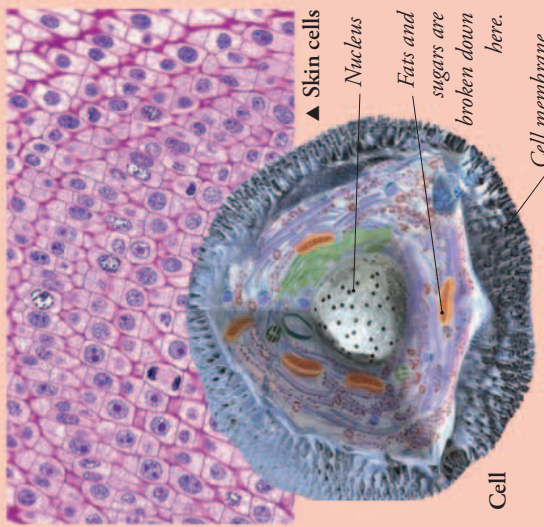
- Human hair will grow between 1/4 inch (6 mm) and 1/2 inch (8 mm) every four weeks.
- On average, a person sheds about 1 lb (0.5 kg) of dead skin cells each year.
- An adult human's skin weighs approximately 11 lb (5 kg).
- Skin is waterproof.
- Fingernails grow four times faster than toenails.





**TAKE A LOOK: CELLS**

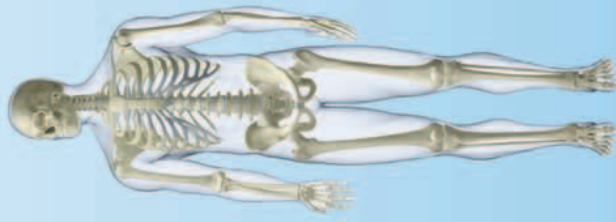
Every living thing begins life as a single cell. Your body is made up of millions of cells so small that, on their own, they can only be seen under a microscope. Cells group together to form tissues, which in turn make up our organs.



- Epithelial cells form a protective outer layer to the human body.
- Fat cells are blob shaped. They get larger as the body stores more fat.
- Nerve cells transfer electrical signals around the body to and from the brain.
- Smooth muscle cells are found in the intestine.
- Photo receptor cells are found in the eyes.

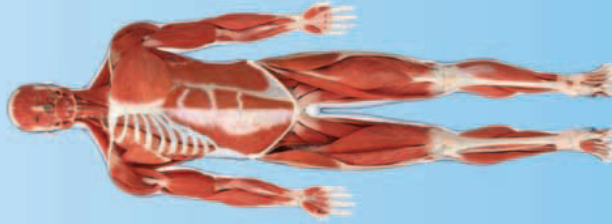
Each of the body's systems has its own job to do. If all are functioning properly, they will work together to ensure the body's overall health.

**The skeletal system** is the moveable skeleton that provides a frame for your body and that protects your internal organs. An adult has 206 bones.



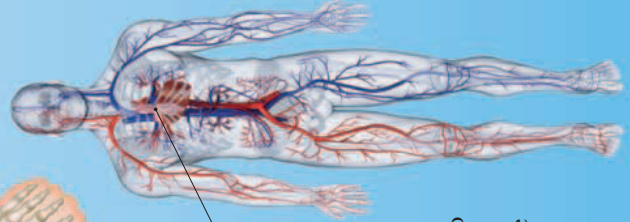
There are about 10 body systems, but it's difficult to state an exact figure, since the muscular system and skeletal system are sometimes combined and referred to as one system.

Skin covers your body. It contains hair follicles, nerve endings, sweat glands, and tiny blood vessels called capillaries.



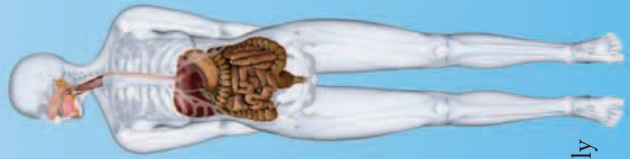
**The muscular system** is made up of muscles attached to bones by tendons, smooth muscles in your organs, and heart muscle. Muscles need a regular blood supply to bring them the oxygen and energy they require to work efficiently.

**The cardiovascular or circulatory system** pumps blood around your body. Blood transports oxygen and other vital substances to your organs and tissues and then removes waste products.



The heart is at the center of the circulatory system.

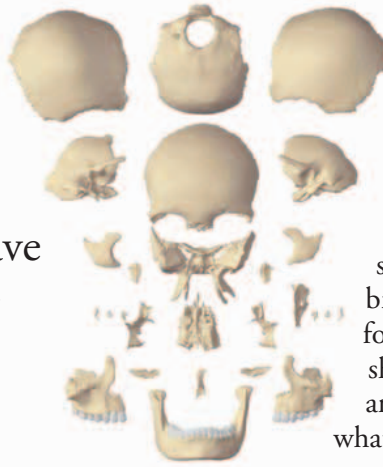
**The digestive system** processes the food you eat, taking out the nutrients your tissues need and getting rid of the waste. It is basically a long tube.





# Bones

Your bones form a framework for your body called a skeleton. If you did not have a skeleton your body would flop all over the place. Bones also protect your soft internal organs (such as your heart) and work with muscles to make you move.

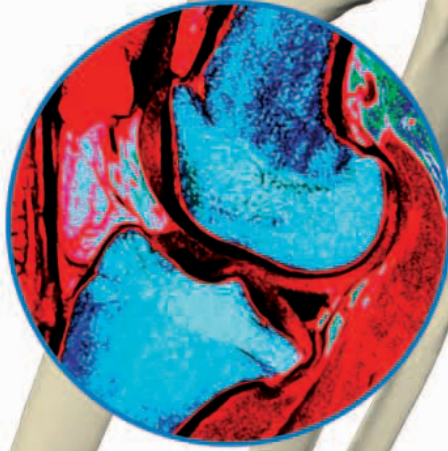


**Pieces of the skull**  
Your skull is not made up of one bone, but of a large number of bones. The pieces of the upper skull lock together to form an incredibly strong casing for your brain, while fourteen bones form your facial bones. The shape of your facial bones and their muscles determines what you look like.

## FAST FACTS

- There are 206 bones in the human body.
- Compared to a steel bar of the same weight, bone is six times stronger.
- Your largest bone is your femur. Your smallest bone is the stirrup bone, which is in your ear. It's no larger than a grain of rice.
- About eighty bones make up the human skull, backbone, and ribs.
- You need calcium in your diet to make your bones hard.
- You have the same number of neck bones as a giraffe: seven.
- A baby's skeleton is largely formed of cartilage (the stuff that makes your nose flexible).
- The thigh bone (femur) is the longest bone in your body. It is about a quarter of your height.
- More than a quarter of your bones are in your hands.

▼ **INSIDE A JOINT**  
*The ends of your bones (in blue below) are covered by smooth cartilage and separated by fluid, so the bones easily slide over each other.*



*The kneecap (patella) protects the front of the knee*

*The thigh bone (femur) is the largest bone in the body.*

*The pelvic (hip) girdle supports abdominal organs and anchors the legs.*

*An inner layer of spongy bone is light in weight but also strong.*

*Arteries (red) supply nutrients and oxygen to the bone's cells.*

*Blood cells are made in the bone marrow.*

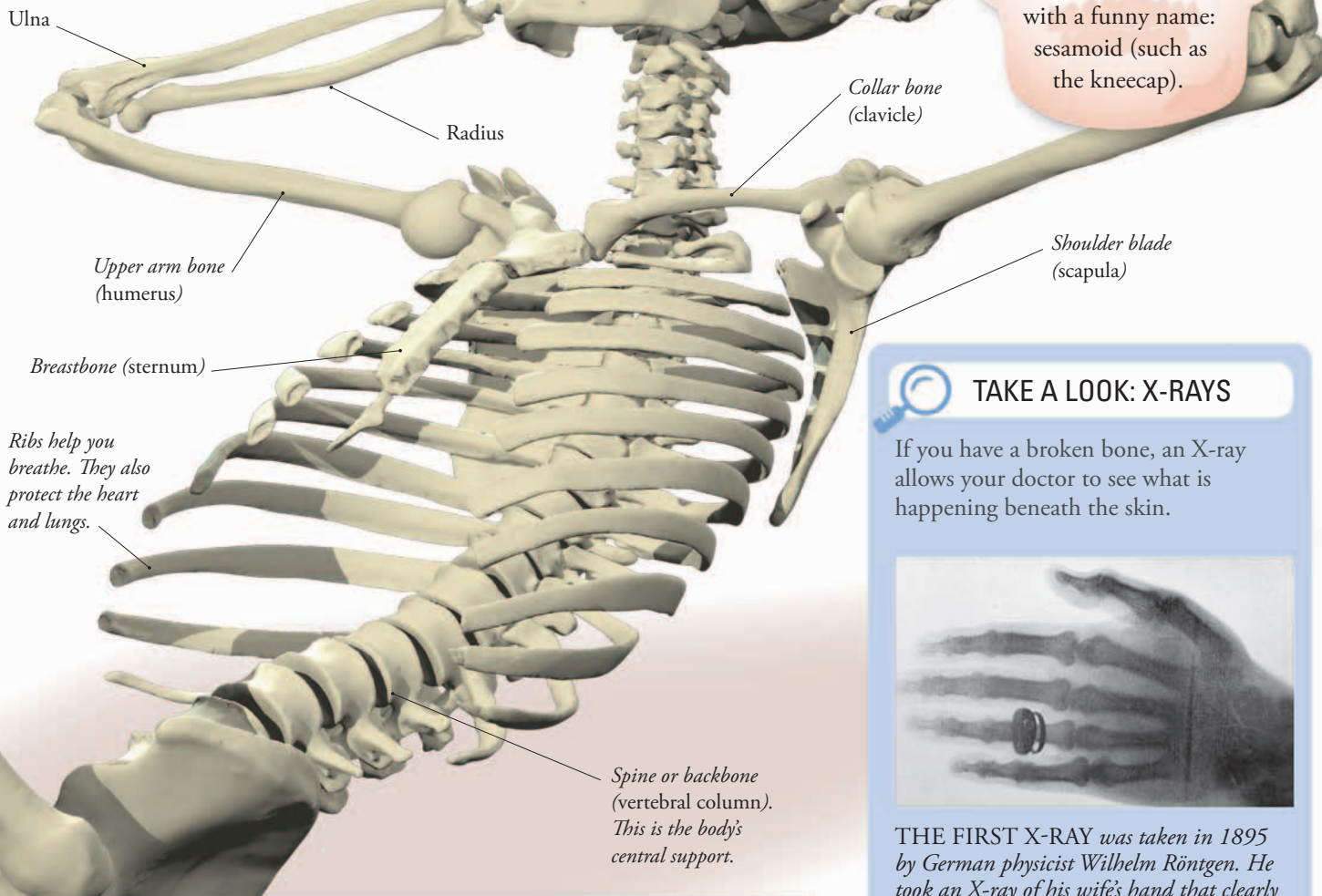
*The heel (calcaneus) is a short bone.*

**Inside a bone**  
Bones are made up of layers, with hard, compact bone on the outside and spongy bone beneath. The spaces in some bones are filled with jellylike bone marrow. Bone marrow stores fat and also produces new blood cells.



## BONES AND JOINTS

Bones are living tissue that contain blood vessels, nerves, and cells. They are strong, but light, and if they get broken, they can heal themselves. You can bend and move your body because you have lots of joints. These are where two bones meet and move over each other.



**WOW!**

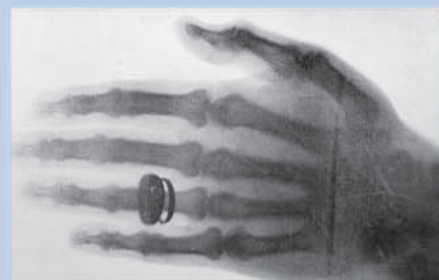
There are four main types of bone: long (such as the thigh bones), short (such as the heel bones), flat (shoulder bones), and irregular (such as your vertebrae). There are also small, round bones with a funny name: sesamoid (such as the kneecap).

THE HUMAN BODY

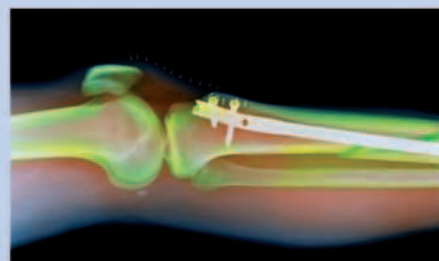


### TAKE A LOOK: X-RAYS

If you have a broken bone, an X-ray allows your doctor to see what is happening beneath the skin.



THE FIRST X-RAY was taken in 1895 by German physicist Wilhelm Röntgen. He took an X-ray of his wife's hand that clearly showed the shadows of the bones and the lighter shadowing caused by the soft tissues.



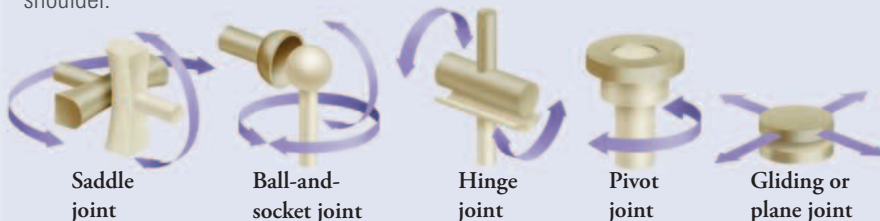
**PINNING A BONE** A bone can heal itself if broken, but after an especially bad break a surgeon may put a metal pin along the bone to hold it rigid while it mends. A fracture can take up to eight weeks to heal.

### TYPES OF JOINT

Some joints (such as your elbows) allow you to bend in one direction. Others (such as your shoulders) allow circular movement.

- Saddle joints are found at the base of your thumbs.
- Ball-and-socket joints are found in your shoulder.

- Hinge joints are found in your knees.
- There's a pivot joint at the top of your spine.
- Gliding joints are found in the ankles and wrists.





# Mighty muscles

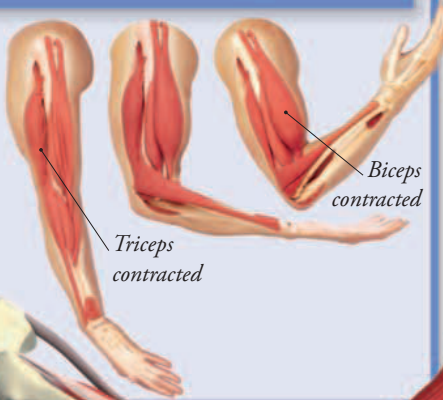
Muscles are tissues that move parts of the body by contracting, or getting shorter. You have around 650 skeletal muscles layered over your skeleton and these make up about half of your weight. They are attached to bones by stringy tendons.

## TYPES OF MUSCLE

There are three types of muscle: skeletal muscles move bones when you want them to. Most muscle is skeletal muscle. Cardiac muscle keeps the heart beating. Smooth muscle is found inside hollow organs such as the digestive tract. You can't control the actions of smooth muscle—they are automatic.

### HOW MUSCLES WORK

Skeletal muscles get shorter and fatter when working—they stretch when relaxed. They work because your brain tells them to. If you want to reach out to grab something, your brain tells your arm muscles to work. The muscles shorten, pulling the arm bones. Muscles work in pairs, because they work by pulling. So in your arm, your biceps works to bend your arm and your triceps straightens it.



*This large, powerful muscle, the gluteus maximus, straightens the hip when you, walk, run, stand up, or climb a hill.*

*Muscles cover the skeleton and give the body its shape.*

## WOW!

Muscles need oxygen to make energy. If starved of oxygen, perhaps during a burst of activity, they produce energy without it and a waste product called lactic acid builds up in the muscle cells. This can cause painful muscle cramps.

*The calf muscle (gastrocnemius) bends your foot downward when you point your toes.*

*The extensor digitorum longus straightens your toes and helps to lift the foot up when you walk.*



The sternocleidomastoid bends your head forward. If just one side contracts, it makes the head turn or tilt.

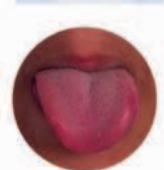
The forehead muscles contract to make frown lines.

**Tendons** These are what link muscles to bones, working with muscles to pull bones into position. They are like cords and are incredibly strong. Some tendons in your hands stretch up to muscles near the elbow, providing huge flexibility and control.

The chest muscle (pectoralis major) pulls your arms in toward your body and is also used to rotate the upper arms.

### FAST FACTS

- Your largest and strongest muscles are in your back, helping you to stand.
- The word muscle comes from the ancient Romans, who thought that muscle movements looked like mice running under the skin. The ancient Roman word for mouse was *musculus*.
- Surprisingly, you use more muscles to smile than you use to frown! It takes 12 muscles to smile and 11 to frown.
- The first drawings of human muscles were published in 1543 by Belgian scholar Andreas Vesalius in his book *On the Structure of the Human Body*.
- Your tongue is made up of muscles.



### TAKE A LOOK: MUSCLE FIBERS

Muscles are made up of bundles of long cells, organized into tissues called muscle fibers. Each fiber is incredibly thin—much thinner than a human hair. This is a magnified image of skeletal muscle fibers.



◀ INSIDE EACH MUSCLE FIBER are long threads of protein. This image has been magnified almost 400 times.



# Blood flow

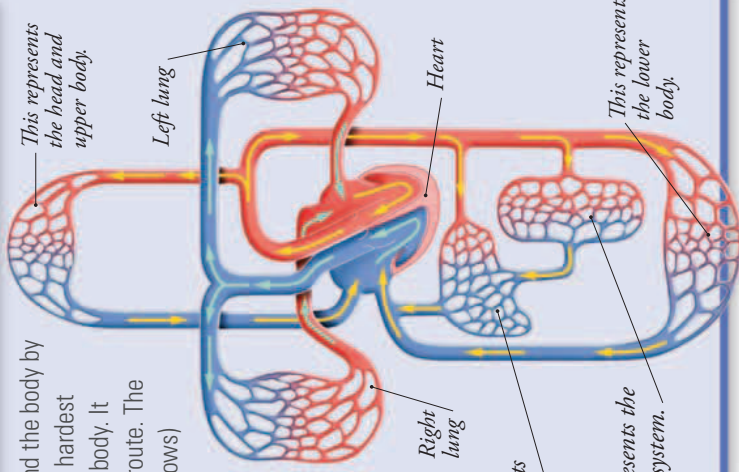
Think of your arteries and veins as a road network for your body. Blood flows through this network, just as trucks move along highways, carrying and delivering the essentials that your cells need and removing waste products. Your arteries and veins are your body's transportation, or circulatory, system.

## WHAT BLOOD DOES

Blood delivers oxygen, water, and nutrients to your body's organs and takes away waste carbon dioxide. It also takes white blood cells to where they are needed, to fight infection, and clots to stop bleeding and form a seal to repair damage if you cut yourself. There's more? Yes! It allows you to maintain a steady body temperature.

## BLOOD CIRCULATION

Blood is pumped around the body by the heart, which is the hardest working muscle in the body. It follows a figure-eight route. The shorter loop (green arrows) takes blood from the heart to the lungs and back. The longer loop (yellow arrows) takes blood to other parts of the body, then returns it to the heart.

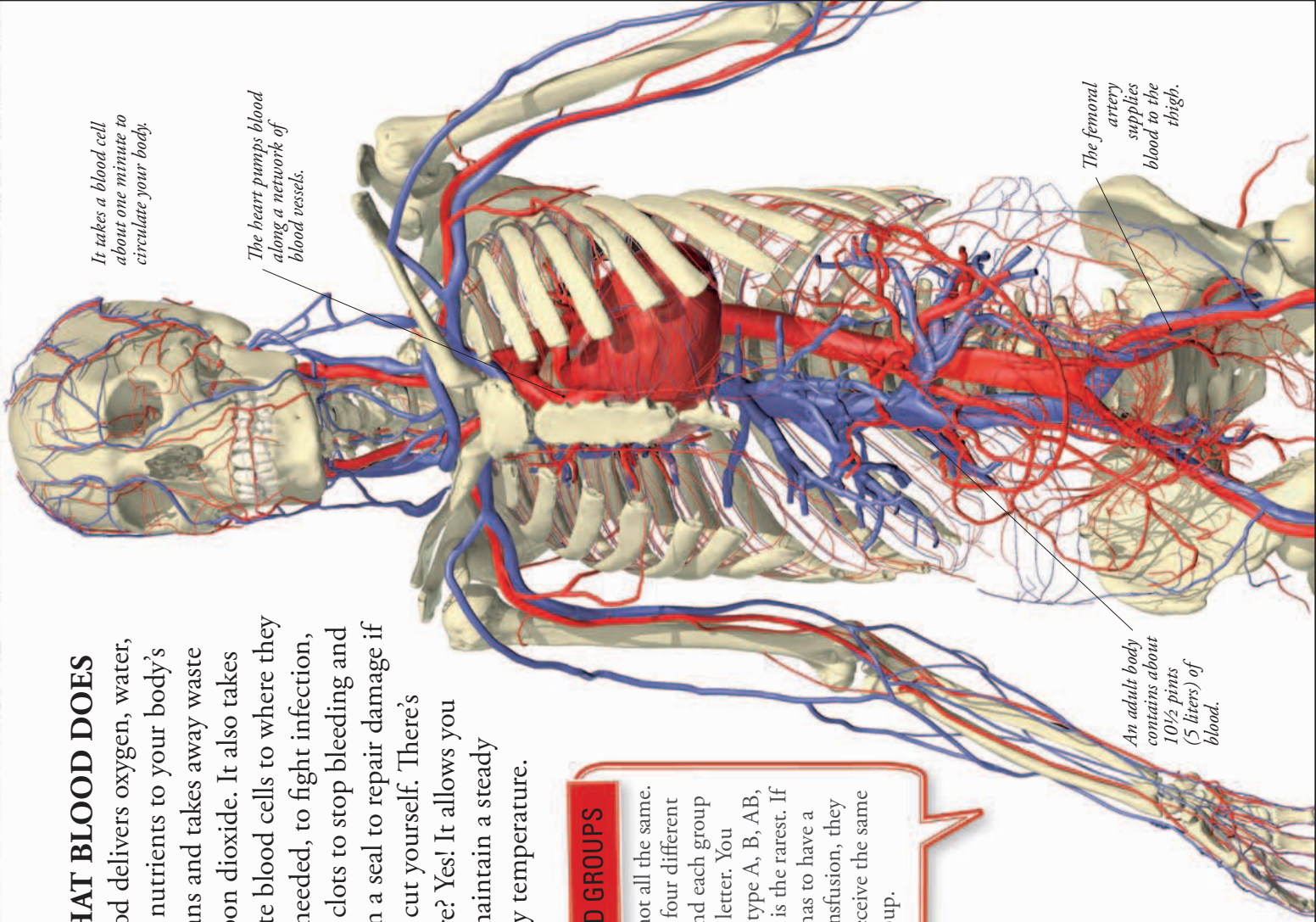


*This represents the liver.*

*This represents the digestive system.*

## BLOOD GROUPS

Blood is not all the same. There are four different groups, and each group is given a letter. You might be type A, B, AB, or O. AB is the rarest. If a person has to have a blood transfusion, they have to receive the same blood group.



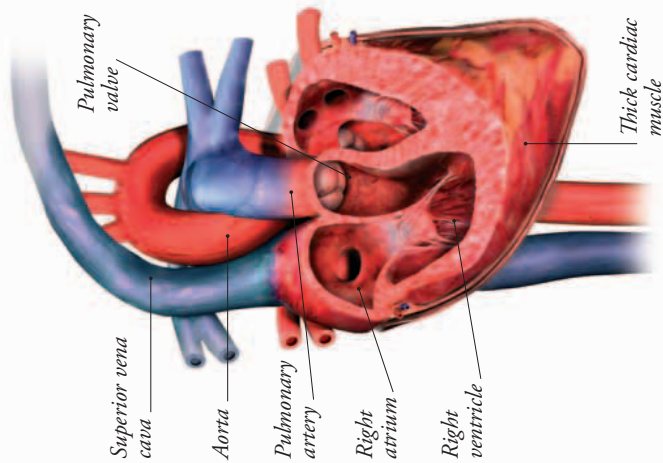


## Your heart

and how it works

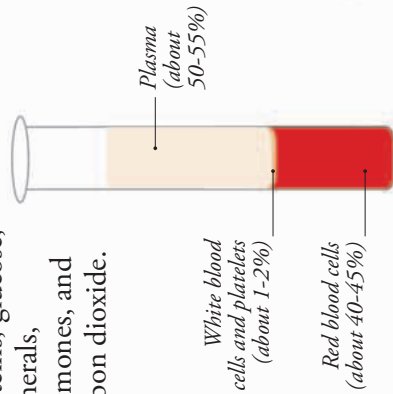
- **Beats per day** Approx 100,000
- **Average weight** Male: 10½ oz (300 g) Female: 9 oz (200 g)
- **Length** 5 in (12 cm)
- **Width** 3½ in (9 cm)

The muscular human heart is about the size of a fist. It pumps blood around your body that takes oxygen to the cells and removes waste. A heart has four chambers: two lower ventricles, and two upper atria. If your heart stops, no other part of your body can work.

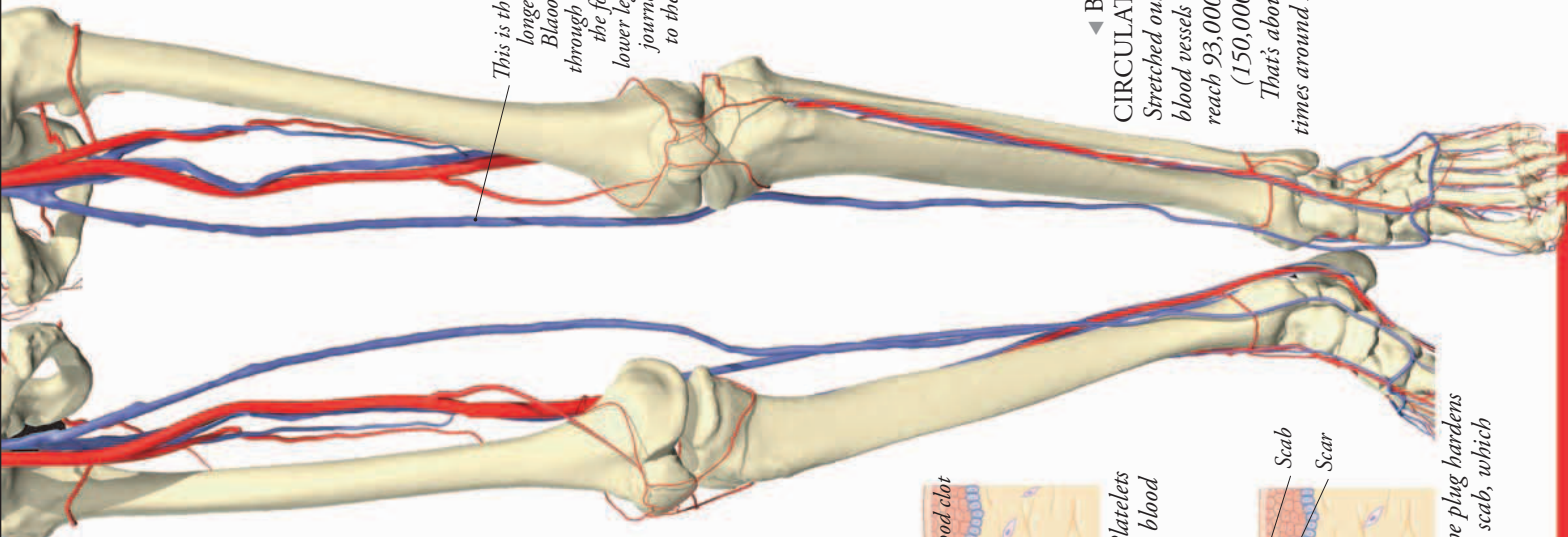


## What goes into blood?

Blood is made up of red blood cells, white blood cells, platelets, and plasma. Plasma is mostly water but also carries dissolved proteins, glucose, minerals, hormones, and carbon dioxide.



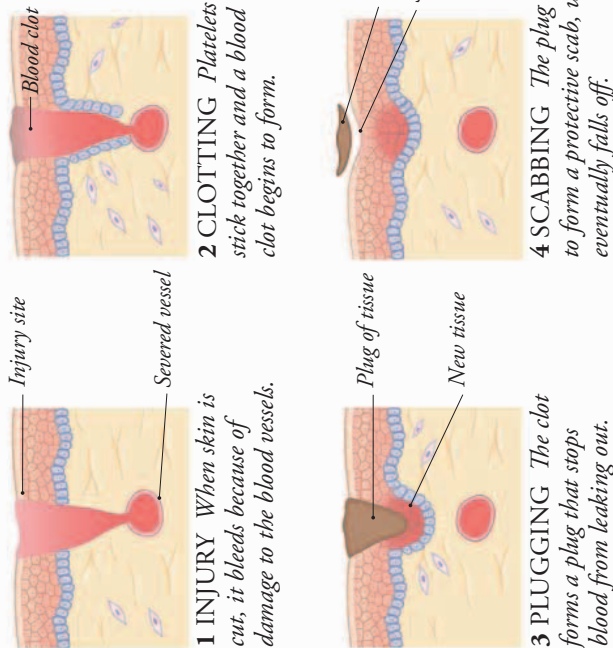
This is the body's longest vein. Blood flows through it from the foot and lower leg on its journey back to the heart.



◀ **BODY CIRCULATION**  
Stretched out, your blood vessels would reach 93,000 miles (150,000 km). That's about four times around Earth.

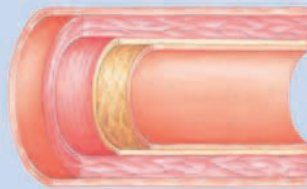
## Blood clots

If you fall over and cut your knee, the cut area scabs over and heals. This happens in a series of steps, as shown below.

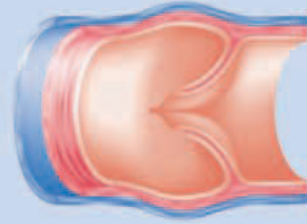


## TAKE A LOOK: BLOOD VESSELS

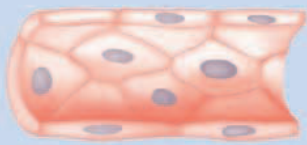
There are three types of blood vessel: arteries, veins, and capillaries. Blood begins its journey around the body in a large artery, called the aorta. Arteries have thicker walls than other vessels because the blood flow is at higher pressure.



▲ **ARTERIES** carry oxygen-rich blood away from your heart. They have thicker walls than veins or capillaries.



▲ **VEINS** carry oxygen-poor blood to your heart. Many veins have valves to stop the blood from running backward.



▲ **CAPILLARIES** are microscopic, with walls just one cell thick. They link your arteries to your veins.



# Think! Act!

Your brain is a complex organ. It's a bit like a big computer but more adaptable. It controls all you do. It makes you think. It allows you to learn. It stores your memories. It makes you who you are.

**FAST FACTS**

- An adult brain weighs about 2 lb 9 oz (1.3 kg).
- Signals travel along neurons at about 250 mph (400 km/h).
- 80 percent of your brain is water.
- Your brain uses about 20 percent of your energy.

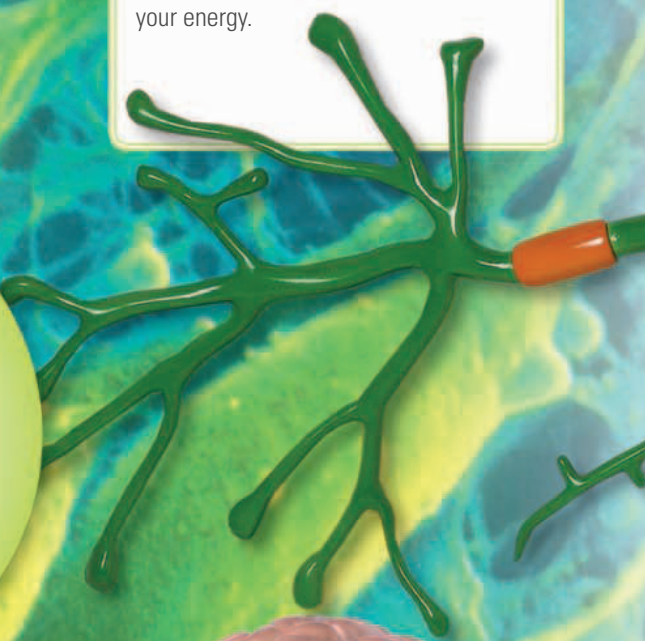
## WHAT IS YOUR BRAIN?

Your brain is a collection of about a hundred billion nerve cells called neurons. These are linked to each other and they share and pass information all day and all night throughout your life.

**WOW!**

Your brain has a joke center, which allows you to understand why a joke is funny. This means that some people with damage to the front of their brains, (particularly on the right-hand side) just don't find jokes funny. Given a joke with a choice of different punchlines, they can't tell which is the funny one.

**Message transfer** Messages constantly arrive in your brain from your body, sent in the form of electrical signals along nerves. Your brain processes those messages and sends out instructions telling your body what to do.



## CENTRAL NERVOUS SYSTEM (CNS)

A bundle of nerves called the spinal cord runs from the brain down your back, protected inside a column of bones, the backbone. The brain and spinal cord form your central nervous system.

**Cross-section of spinal cord**

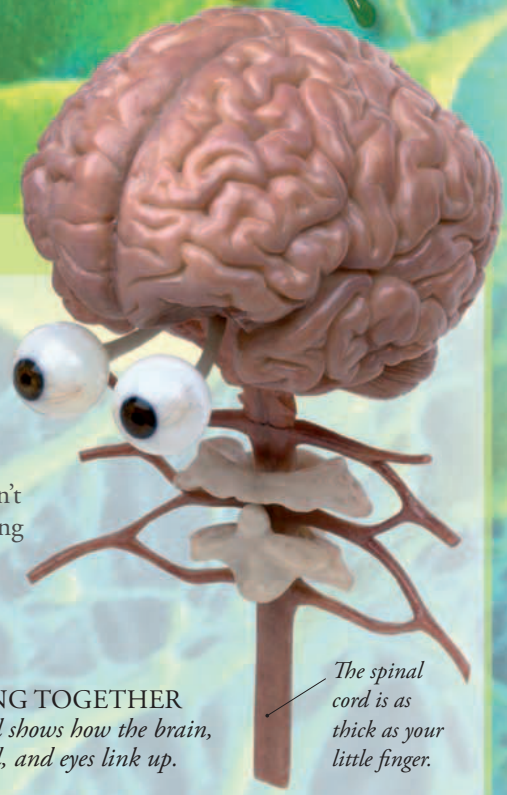
*Spinal nerve*



► **THE SPINAL CORD** transports information from the brain to the rest of the body and back via pairs of spinal nerves.

The central nervous system allows you to make voluntary actions such as eating, reading, and walking, as well as controlling many actions itself. For example, you aren't aware of the muscles working in your stomach—they work automatically.

► **FITTING TOGETHER** This model shows how the brain, spinal cord, and eyes link up.



*The spinal cord is as thick as your little finger.*



**Neurons** are thin cells that carry electrical signals called nerve impulses. A neuron has a cell body, with short, spreading projections called dendrites. An axon connects to other neurons.

*The axon, a nerve fiber, takes electrical impulses away from the cell body to other neurons.*

*The nucleus of the cell controls the cell's activity.*

Cell body

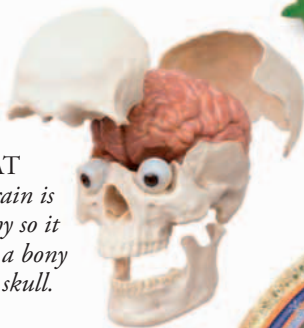
*Dendrites pick up nerve signals.*

BRAIN CELL OR NEURON



**The nervous system** is made up of the CNS and the peripheral nervous system, which consists of nerves that branch to the rest of your body. It's hardworking and fast; a nerve impulse travels from the big toe to the spinal cord in one-hundredth of a second.

► **HARD HAT**  
*The human brain is soft and squishy so it is protected in a bony case called the skull.*



*The thalamus passes messages between the brain and spinal cord.*

*The heavily folded cerebrum is the largest part of your brain.*

*The cerebral cortex is the surface of the cerebrum.*

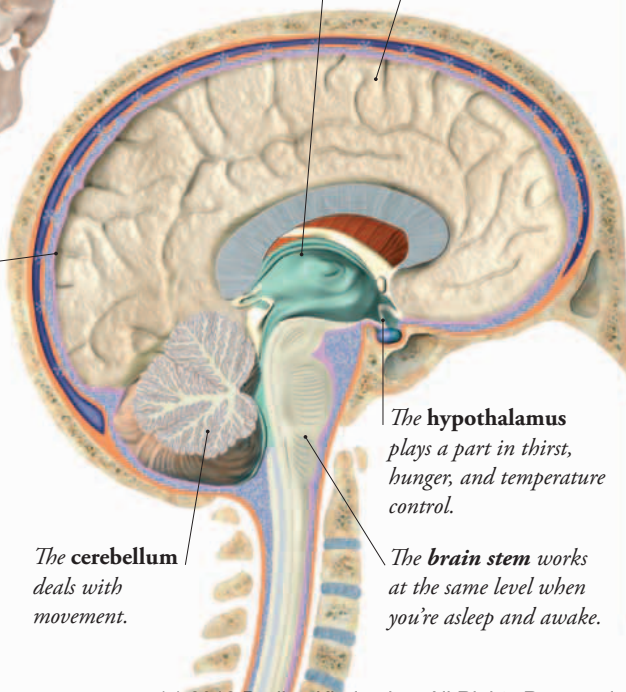
**Parts of the brain**

The main regions of the brain are the cerebellum, the brain stem, and the cerebrum. The cerebrum is responsible for many complex everyday activities, from eating to speaking.

*The cerebellum deals with movement.*

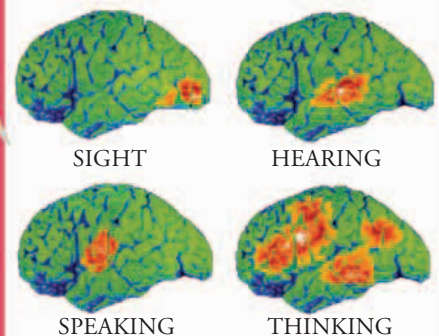
*The hypothalamus plays a part in thirst, hunger, and temperature control.*

*The brain stem works at the same level when you're asleep and awake.*



**YOUR BRAIN**

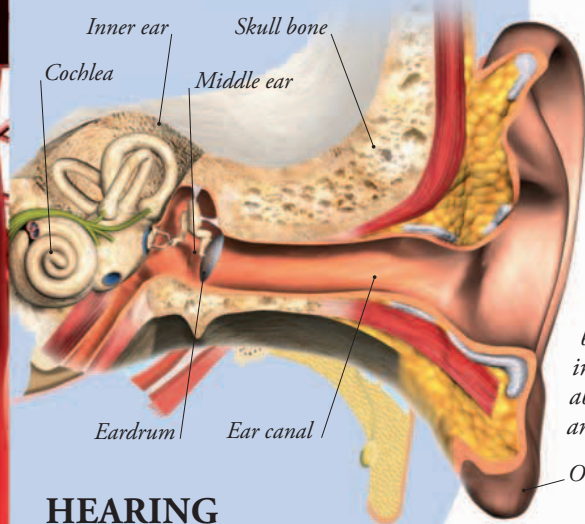
Sight, hearing, speaking, and thinking are controlled in different areas of the cerebrum. Hearing uses an area linked to the ears' nerves. Sight involves a small area linked to the eyes' nerves. Thinking and speaking use large areas of the brain. Heat scans show the different areas.





# Sensing the world

Humans have five senses: sight, hearing, touch, smell, and taste. Your senses tell you about the world around you. They work because billions of nerve cells flash messages to your brain, which interprets the messages and tells you what you are sensing, whether good or bad.

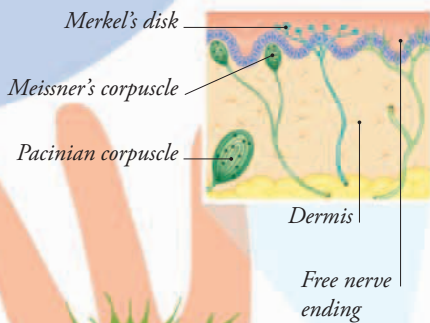


◀ **INSIDE THE EAR**  
Your ear is made up of three main parts—the ear (auditory) canal, the middle ear, and the inner ear.

**BALANCE, TOO!**  
Your ear helps you to balance. Hair cells in the inner ear tell your brain about your body's position and movements.

## HEARING

Sounds are made up of vibrations, which are funneled inside the ear by the outer ear. Soundwaves first travel down the ear canal and vibrate the eardrum. These vibrations reach the cochlea. From here, messages pass to the brain, which interprets the vibrations as the sounds we recognize.



## TOUCH

You have about three million pain sensors, and most of these are in your skin. Your fingertips are particularly sensitive. You also have touch receptors that detect light touch, pressure, vibration, heat, and cold.

◀ **TOUCH SENSATIONS** Skin layers are full of touch receptors. Some receptors are contained in a capsule, while others are free nerve endings.

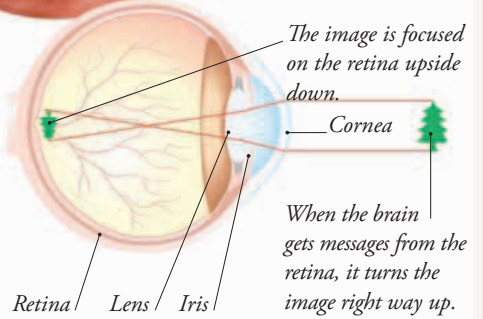
## SIGHT

The eye works like a camera. Light from an image passes through the cornea, is adjusted by the lens behind it, and forms an upside-down image on the retina at the back of the eye. This is translated by the brain.



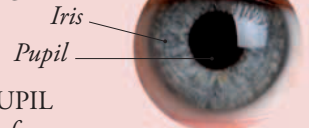
### SIGHT

■ Messages about the image travel from your eye to your brain as nerve impulses. Your brain turns the messages into the detailed image that you see.



### TAKE A LOOK: IRIS

Your eye will react differently depending on how bright the light is that is shining into it. How it reacts is controlled by the iris, a ring of muscle.



#### ► IRIS AND PUPIL

The colored part of your eye, called the iris, has a hole in the middle called the pupil. In bright light, the pupil shrinks to prevent too much light from getting into your eye. In dim light, the pupil expands to allow more light into your eye.



Dim light

Bright light



## SMELL

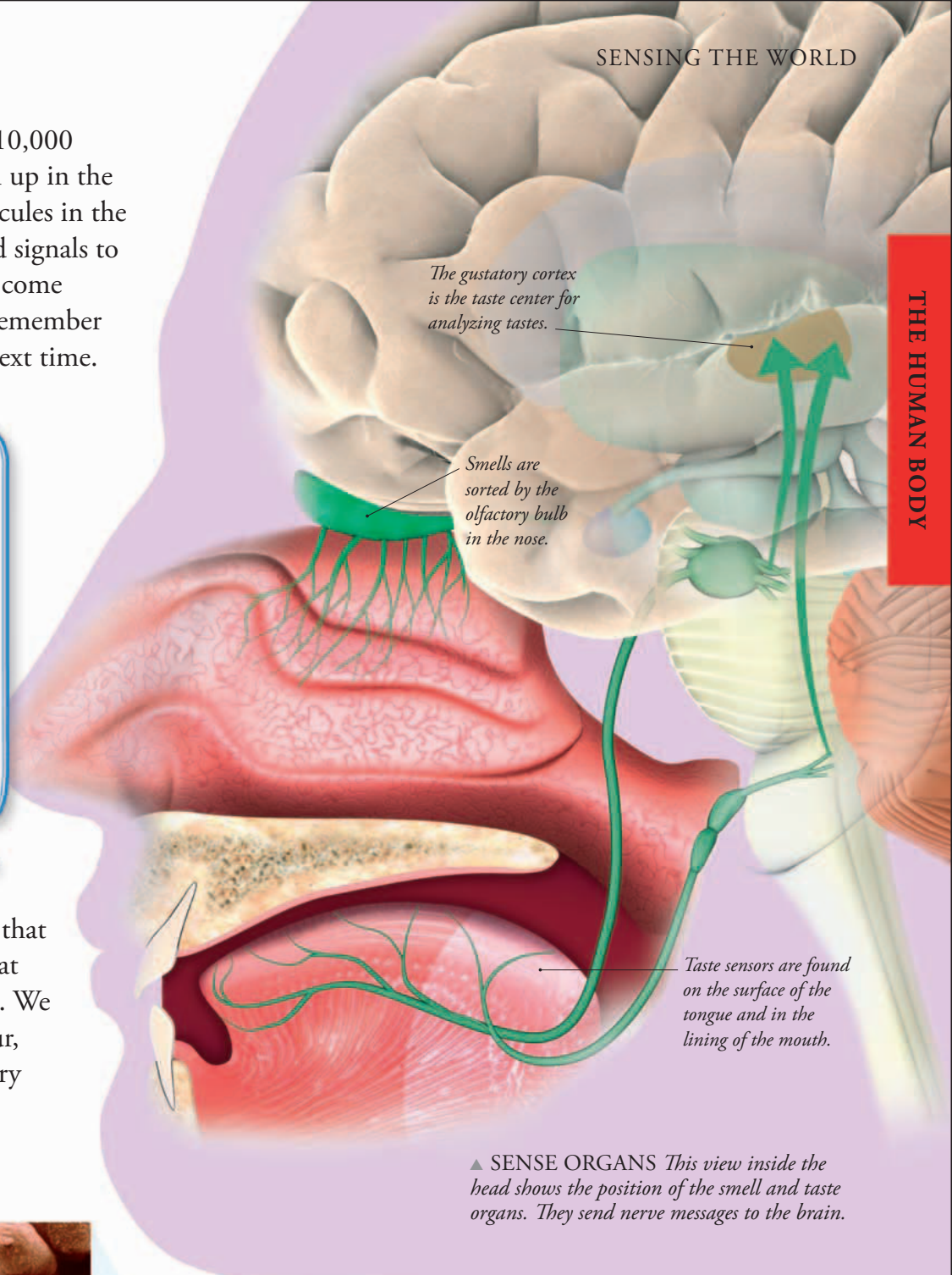
Your nose can recognize up to 10,000 different smells. Receptors high up in the nasal cavity pick up smell molecules in the air that you breathe in and send signals to your brain. If your brain hasn't come across the smell before, it will remember it so that you recognize it the next time.

### TELL ME MORE...

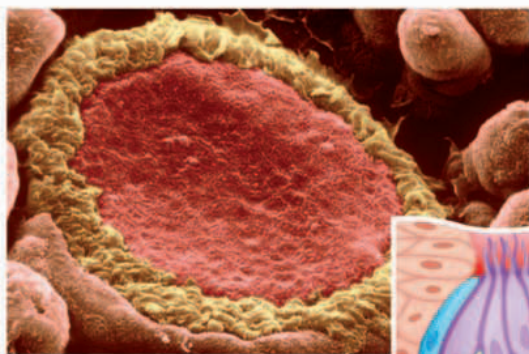
- Smell and taste work together. The flavor of food depends more on smell than taste. This is why it's difficult to taste food if you have a blocked nose.
- Your senses of smell and taste protect you. If you smell smoke, it warns you of fire. You can smell if food has spoiled. Poisonous food often tastes bitter to make sure you spit it out.

## TASTE

It is now thought to be a myth that you can taste particular flavors at different places on your tongue. We have five basic tastes: sweet, sour, salty, bitter, and umami (a savory taste), and these can usually be picked up all over your tongue.



▲ SENSE ORGANS This view inside the head shows the position of the smell and taste organs. They send nerve messages to the brain.



▲ TASTE RECEPTORS The surface of your tongue is covered with tiny bumps (papillae). Some of these contain taste buds, made up of taste cells that have tiny taste hairs. These hairs detect chemicals in food, and your brain tells you the flavor.

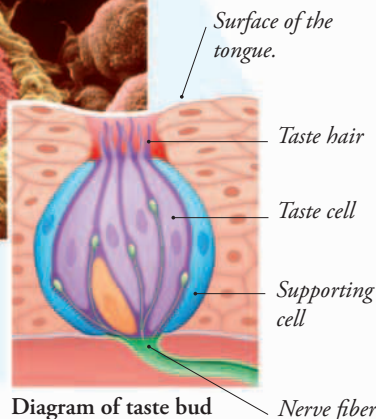


Diagram of taste bud

### FAST FACTS

- Children have around 10,000 taste buds, but the number of taste buds declines with age.
- People who can't smell are called "anosmic."
- If you only had one eye from birth, the world would look two-dimensional.
- There are 100 touch receptors in each of your fingertips.
- Girls usually have more taste buds than boys.
- The sense of smell is thought to be 20,000 times more powerful than the sense of taste.



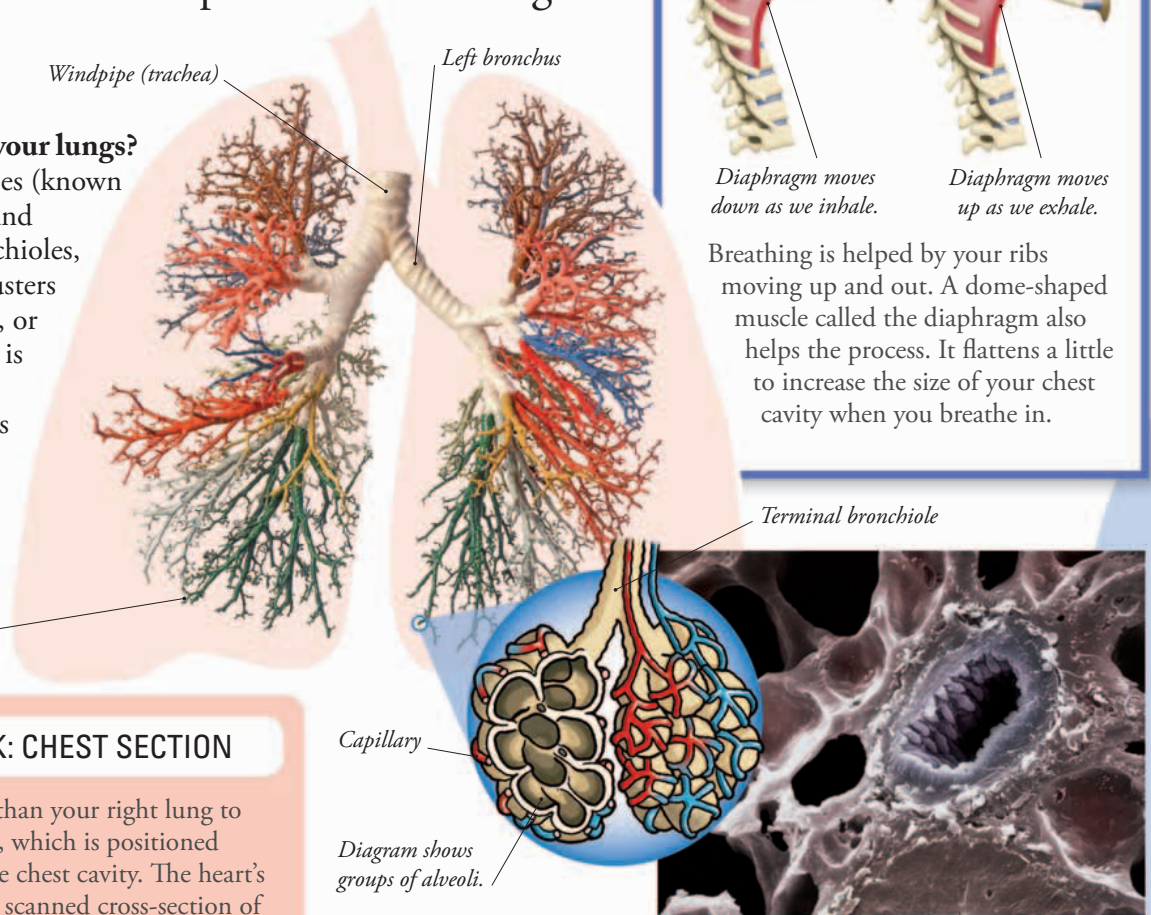
# Take a breath

You need to breathe constantly to take in oxygen. You do this by breathing in air, which is taken down your windpipe and into your lungs, where the oxygen is removed and enters the blood. At the same time, carbon dioxide passes into the lungs.

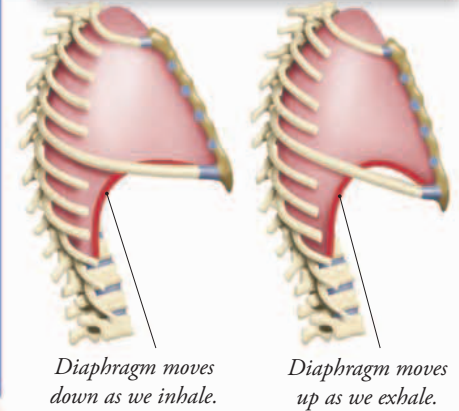
## What happens inside your lungs?

Inside each lung, air tubes (known as bronchi) get smaller and smaller, becoming bronchioles, each of which end in clusters of small, flexible air sacs, or bags, called alveoli. This is known as the bronchial tree, because it resembles an upside-down tree.

Each of the branching networks ends in a bronchiole, which leads into groups of alveoli.



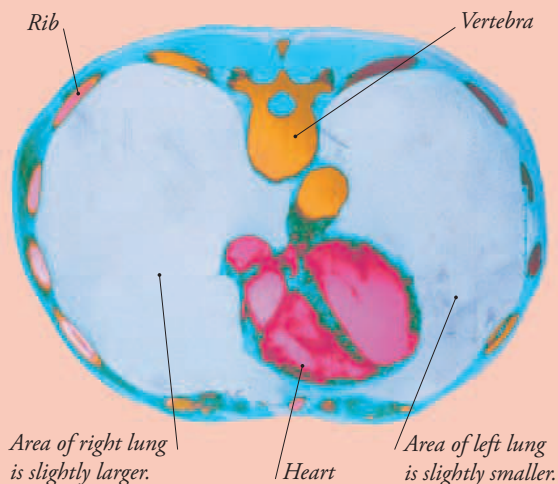
## BREATHE IN, BREATHE OUT



Breathing is helped by your ribs moving up and out. A dome-shaped muscle called the diaphragm also helps the process. It flattens a little to increase the size of your chest cavity when you breathe in.

## TAKE A LOOK: CHEST SECTION

Your left lung is smaller than your right lung to make room for the heart, which is positioned toward the left side of the chest cavity. The heart's position can be seen in a scanned cross-section of the chest, taken from above.



▲ **ALVEOLI** Oxygen passes through the walls of the alveoli into capillaries (thin-walled blood vessels: see p.279–280).

▲ **BRONCHIOLI** This greatly magnified image shows the end of a bronchiole (in blue) surrounded by a group of alveoli. There are more than 300 million alveoli in the two lungs.

## FAST FACTS

- Flattened out, a pair of lungs would cover a tennis court.
- An average person takes about 12 to 15 breaths a minute when at rest. After physical activity they take in about 60 breaths a minute.
- The trachea is about 4 in (11 cm) in length.
- Your lungs act like giant sponges. They take in air instead of water.
- Each minute around 1½–1½ gallons (5 and 6 liters) of air pass into and out of your lungs.



## THE ROUTE IN

When you breathe in, air first travels down your pharynx (throat), then your larynx (voice box), before entering your trachea (windpipe) to get to your lungs. About 20 C-shaped rings of cartilage hold the trachea open.

### Making sounds, too

Breathing is also connected with making sounds. Two membranes, the vocal cords, stretch across the larynx. When you breathe out, air passes over the vocal cords, making them vibrate. Your lips and tongue shape these sounds into speech.

*Muscles between the ribs help to move them up and out as you breathe in.*

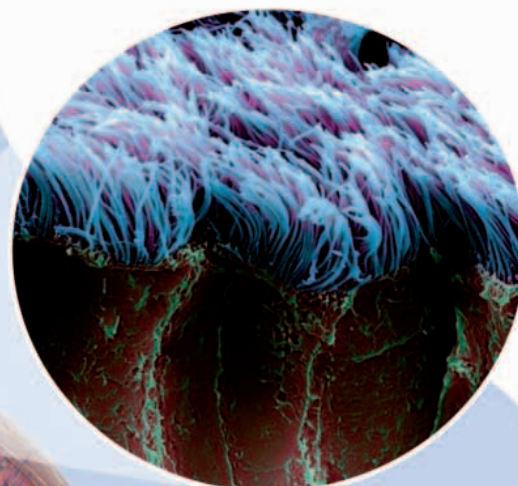
Nasal cavity

Pharynx

*The epiglottis moves over the entrance to the larynx when swallowing.*

*The larynx links the throat to the trachea.*

*The trachea branches into two tubes, or bronchi, one for each lung.*



▲ **CILIA** *The trachea is lined with millions of microhairs. These are called cilia and they beat with a wavelike motion to propel mucus, microbes, and dust up the trachea to be coughed up.*

*Interior of left lung showing the branching arteries (red), veins (blue), and airways (bronchi, shown in gray).*

Heart

## WOW!

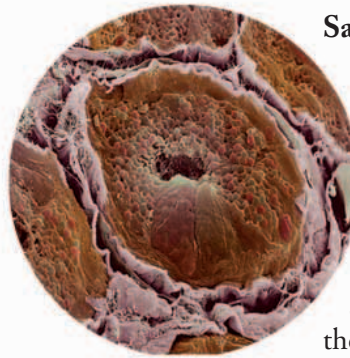
We take a breath some 23,000 times each day. Each breath results in a constant flow of oxygen to the cells. You cannot survive for long without this supply.

*The diaphragm separates the chest cavity from the abdomen.*



# Food flow

We eat to refuel our bodies. We need fuel from food to provide energy, as well as for growth and repair. Digestion is the process by which the food we eat is broken down to extract the nutrients we need. Waste matter is then passed out of the body.

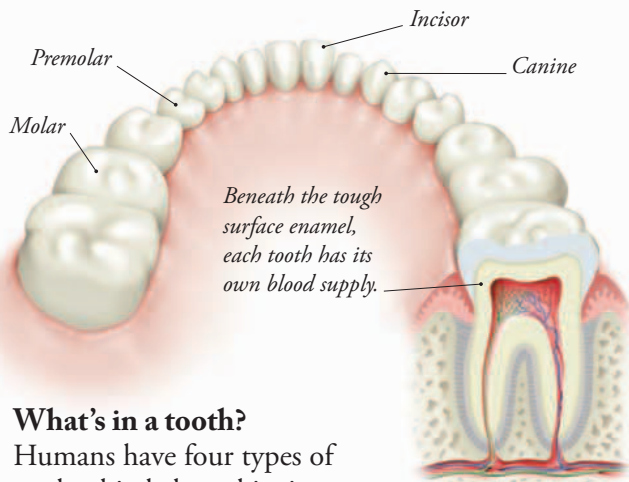


## Salivary glands

Saliva is produced by glands in the mouth. It makes food slippery and begins the process of digestion. About 3 pints (1.5 liters) of saliva is secreted into the mouth each day.

## TAKE A MOUTHFUL

Digestion begins with ingestion when you take in and chew food, mixing it with saliva to make it easier to swallow. Swallowing moves the food into the esophagus, from where it goes into the stomach.

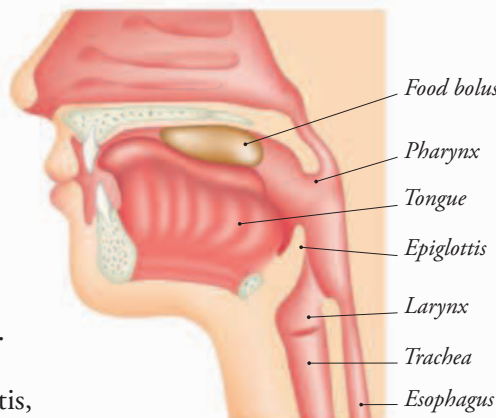


### What's in a tooth?

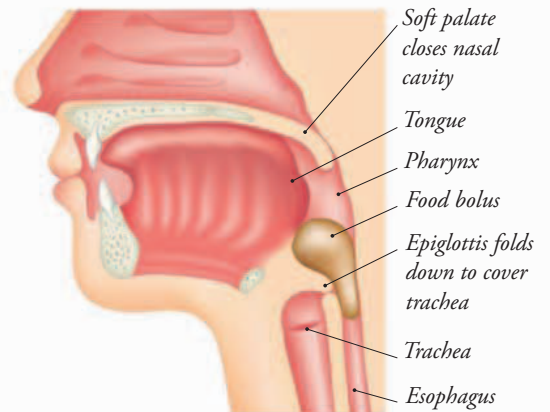
Humans have four types of teeth: chisel-shaped incisors cut, while pointed canines tear. The flatter premolars and molars crush and grind. These are the largest teeth.

### Down it goes

Once food has been chewed, it is swallowed as a ball called a bolus. It is prevented from entering the larynx and trachea by the epiglottis, a flap of cartilage.



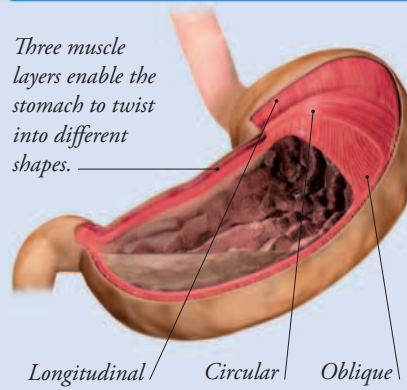
▲ **CHEWING FOOD** The bolus of food is about to be swallowed. The epiglottis is in its usual position.



▲ **SWALLOWING FOOD** On swallowing, the epiglottis moves down to close entry to the trachea.

## THE STOMACH AND HOW IT WORKS

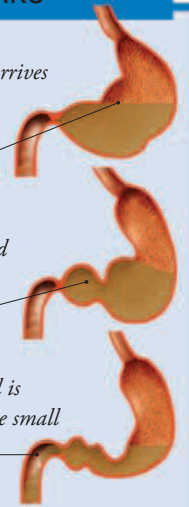
Three muscle layers enable the stomach to twist into different shapes.



When food arrives your stomach stretches to store it.

Acid and food are churned together.

Churned food is passed into the small intestine.



■ **Inside the stomach** Food enters your stomach about eight seconds after you swallow. It is mixed with acids (called gastric juice) and churned into a semiliquid. Up to 6 pints (3 liters) of gastric juices are made in the stomach every day.

▲ **A GOOD CHURNING** A meal spends up to four hours in your stomach before being passed slowly on into the small intestine.



**BEYOND THE STOMACH**

After leaving the stomach, food enters the small intestine. This is where nutrients are absorbed from the food for use by your body. Material that isn't digested passes into the large intestine, where it's turned into feces.

**WOW!**

Why does your stomach "growl" when empty? If you are hungry, your stomach receives signals from the brain to begin digestion. The muscles begin to work and acid is mixed in the stomach without food. This produces vibrations we hear as growls.

Food enters the mouth where the tongue assesses whether it is sweet, savory, hot or cold.

Food is swallowed and passes into the esophagus. It is moved by muscle contractions called peristalsis.

The pancreas constantly releases digestive juices into the small intestine.

The liver is thought to have more than 250 different functions. Among these, it processes nutrients, removing what your body needs. It also stores glucose (which gives you energy) and breaks down harmful substances.

The gall bladder stores bile, a digestive juice. Bile is used to break down fats.

The small intestine is a long tangled tube that produces many different enzymes to digest food. The tube is covered inside with tiny, fingerlike projections called villi. These increase the intestine's surface area for the absorption of nutrients.

Mucus

Gastric pit

The large intestine is where the last nutrients are extracted, together with water. Undigested material is combined with other waste products and moved on to the rectum before passing out of the body.

The large intestine is wider than the small intestine.

**FAST FACTS: DIGESTION**

- The stomach can store about 3 pints (1.5 liters) of food.
- A meal takes 18–30 hours to pass through the human body.
- The small intestine is about 17 ft (5 m) in length.
- The large intestine is about 5 ft (1.5 m) in length.
- The liver, the body's largest internal organ, produces about 2 pints (1 liter) of bile a day.
- The large intestine contains millions of bacteria.

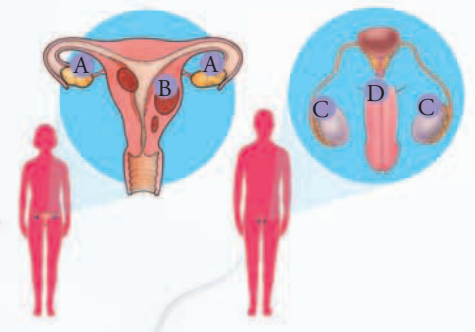
**SOLID OR LIQUID**

Solid food takes longer to break down, which means that a meal stays in the stomach for much longer than a drink, which may pass through in minutes.



# The start of life

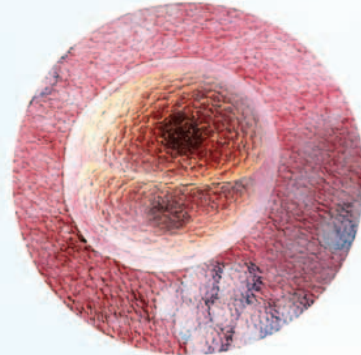
Human life begins after a sperm fertilizes an egg and the egg develops in the uterus (the womb). A fertilized human egg takes about nine months to grow into a baby ready for birth. In the uterus, the fetus depends on the placenta (the tissue that links the mother's and fetus's blood) for all its needs.



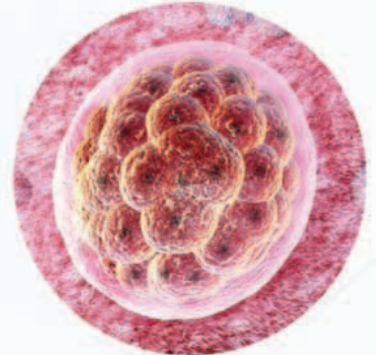
▲ **REPRODUCTIVE ORGANS**  
 Women have two ovaries (A), where eggs, or ova, are stored, and a uterus (B), where a baby is nourished and grows until birth. Men have two testes (C), where sperm are made. They also have a penis (D) through which the sperm travel to get to the eggs.

## FERTILIZATION

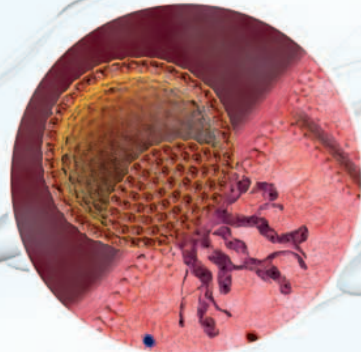
Millions of sperm swim toward the egg, propelled forward by flexible tails, but usually only one will fertilize it. On contact, the sperm and egg merge to create a single cell—the fertilized egg. The cell then begins to divide.



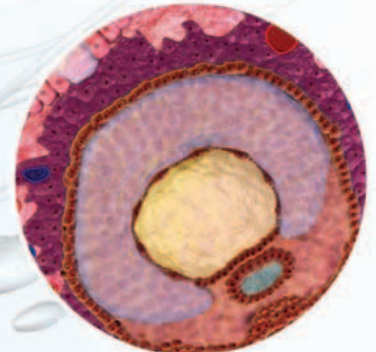
**1 WITHIN 36 HOURS** the fertilized egg has divided into two cells. Twelve hours later it has divided into four cells, and so on.



**2 THREE TO FOUR DAYS** after fertilization, there is a cluster of 16 to 32 cells. The cluster enters the uterus.



**3 ABOUT SIX DAYS** after fertilization, the cell cluster forms a hollow cavity. It attaches itself to the lining of the uterus with rootlike growths.



**4 ABOUT EIGHT DAYS** after fertilization, an embryo begins to form. New cells will form tissues and organs as a baby develops.

Each sperm has a rounded head and a long tail.

After an egg is fertilized it begins to form a barrier to other sperm.

## ULTRASOUND SCAN

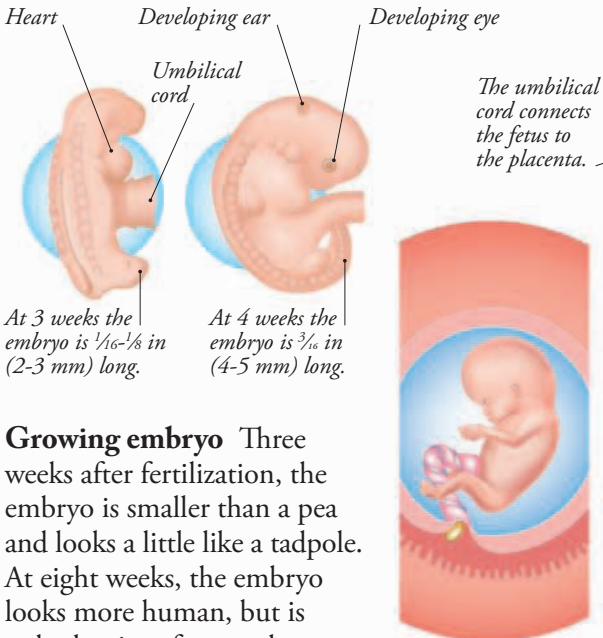
■ This is a scan of a fetus inside the womb, taken between four and six months into pregnancy. It was produced using sound waves to form a picture, which was then turned into a three-dimensional (3-D) image. 3-D scans first appeared in 1987.





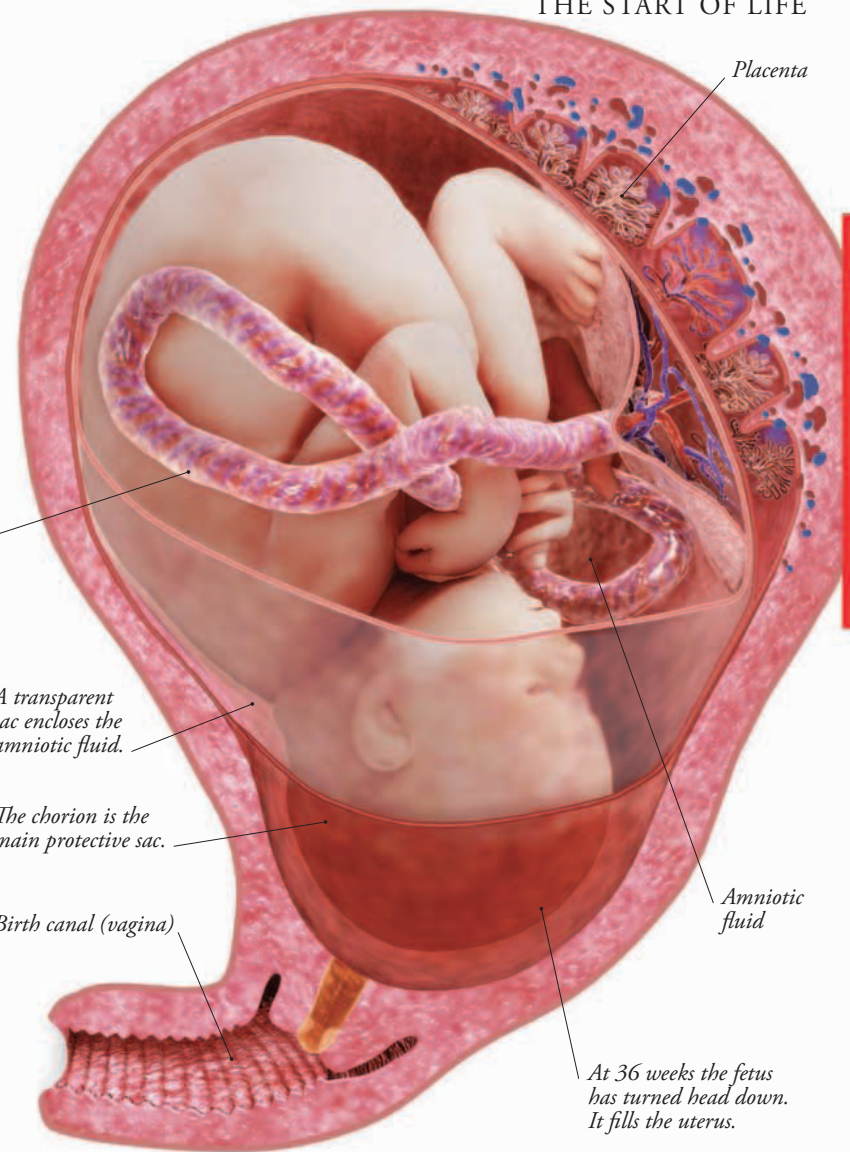
## GROWING EMBRYO

Cells continue to divide as the embryo develops. They become specialized, with the head, brain, body, and heart taking shape first, followed by the arms (initially as buds) and, finally, the legs. From eight weeks after fertilization, the baby is known as a fetus.



**Growing embryo** Three weeks after fertilization, the embryo is smaller than a pea and looks a little like a tadpole. At eight weeks, the embryo looks more human, but is only the size of a strawberry. The fetus is fully developed at 24 weeks. The last stage of development is growth.

▲ At 8 weeks the embryo starts to move and is 1-1/4 in (25-30 mm) long.



THE HUMAN BODY

## TAKE A LOOK: PREGNANCY



▲ DURING the first three months of pregnancy, called the first trimester, the mother's breasts become larger. Many pregnant women feel sick around this time.

▲ DURING the second trimester, the mother's breasts continue to enlarge, her heart rate increases, and her enlarging womb shows as the fetus grows inside.

▲ DURING the third trimester, the mother's intestines and organs are pushed up. She may feel tired, have back pain, and get breathless when walking around.



**Newborn babies** adapt quickly to life in the outside world. The umbilical cord, by which it was attached to its mother during pregnancy, is cut. The baby takes its first breaths, forcing its circulation to start working.





TELL ME MORE...

Run and jump, eat a varied diet, and drink lots of water. All these things will help your body to stay as healthy as it can.

# Stay healthy

You have just one body for life, so it makes sense to look after it. Giving your body the best chance you can means it will work better for you. That begins with a healthy, mixed diet.

## EAT A RAINBOW

Foods can be divided into groups, such as grains and cereals and meat and fish. It is good to eat a range of foods every day, and choose from all the major food groups, eating more of some and less of others (for example, you should eat more fruit than meat or fish). Thinking of food groups as a rainbow of colors can help to separate foods into these groups.



**OIL/SUGAR**  
Small quantities of oil are needed in the diet. A good source is oily fish, such as salmon. Try to limit sugar.

**MEAT, FISH, BEANS, AND LENTILS**  
provide protein for growth and repair, as well as vitamins and minerals.

**DAIRY** products, such as cheeses and yogurts, are a rich source of calcium, which helps your bones and teeth.

**FRUIT** is a source of vitamins, water, and fiber, as well as natural sugars.

**VEGETABLES** are rich in fiber and in the vitamins and minerals our bodies need for growth and repair.

**GRAINS** Bread, rice, and pasta, as well as potatoes, are largely carbohydrate, the body's main source of energy.





## HEALTH PROBLEMS

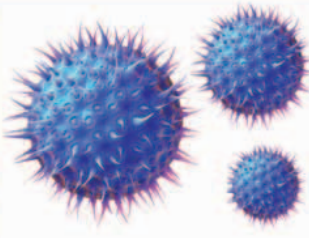
It's not always easy for someone to stay well. There may not be access to clean drinking water, or food may be restricted. Malnutrition, which is when somebody doesn't have enough of one or more of the food groups, is a serious problem in some parts of the world. But if your immune system is working well, it will act to protect your body from illness, fighting off the viruses and bacteria that may cause you harm.



### WHAT MAKES US SICK



■ **Bacteria** are single-celled organisms. Most are harmless, but certain bacteria invade our bodies to cause illness. Tuberculosis is caused by bacteria.



■ **Viruses** are far smaller than bacteria. They attack our cells from the inside, taking them over. Colds and flu are the result of a viral infection.



■ **Fungi** usually cause infection on the skin's surface, like dandruff, but other fungi can cause serious illness inside the body by damaging the cells.

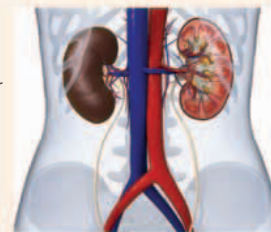


**Allergies** Sometimes the immune system doesn't work properly, identifying things as a threat and attacking them when they aren't. This can cause an allergic reaction. A person might begin sneezing, for example, when in contact with pollen or dust.

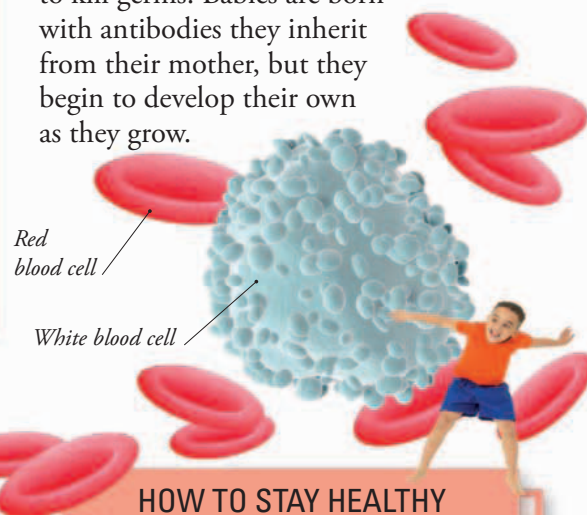
◀ **HAYFEVER**  
Increasing numbers of people around the world are suffering from allergies, such as hayfever. Hayfever is an allergic response to plant pollen. This can be worse at particular times of year, when the pollen count is high.

## KIDNEYS

- Your two kidneys are at the back of your abdomen.
- The kidneys control the amount of fluid in the body and filter liquid waste from your blood.
- Filtered waste is removed to the bladder and then expelled as urine.



**White blood cells** These cells fight bacteria and viruses that might make you sick. Some produce antibodies that work to kill germs. Babies are born with antibodies they inherit from their mother, but they begin to develop their own as they grow.

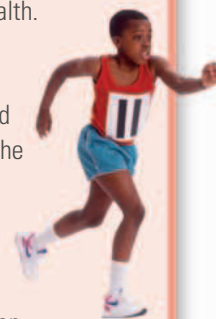


## HOW TO STAY HEALTHY



■ Vitamins and minerals are found in many foods, and are essential to general body health.

■ Exercise helps strengthen the heart, lungs, and muscles. It also helps to keep the body supple.



■ Water is needed for all of the body's processes to function properly. Dehydrated cells will not perform at their best.

■ Good hygiene helps to keep germs away. Brushing teeth helps combat tooth decay by cleaning teeth of the bacteria that cause it.





# Glossary

**Alveoli** Tiny sacs in the lungs through which oxygen and carbon dioxide pass to and from the blood.

**Altitude** Height above sea level.

**Amphibian** Cold-blooded vertebrate such as a frog or newt.

**Apprenticeship** Working under a skilled craftsman to learn a trade.

**Artifact** Object made by human workmanship.

**Arteries** Blood vessels that carry oxygen-rich blood away from the heart.

**Artificial intelligence** A branch of science that aims to create intelligent machines.

**Astrolabe** An ancient instrument used to calculate the position of stars in the sky.

**Atmosphere** The mass of air that surrounds the Earth.

**Atoll** A ring of coral reef surrounding a central lagoon.

**Bacteria** Single-celled microorganisms that can be helpful or harmful.

**Big bang** The cosmic explosion that created the universe billions of years ago.

**Biodiversity** The range of different organisms that live in a particular area.

**Biofuel** Any fuel made from biological matter, such as plants or animal waste.

**Biome** Any of Earth's major ecosystems with a particular climate and vegetation.

**Black hole** A collapsed star in which the pull of gravity is so strong that not even light can escape it.

**Calligraphy** The art of decorative writing.

**Camouflage** A color or pattern on an organism's body that allows it to blend in with its surroundings.

**Canopy** The uppermost leafy layer of a tree or forest.

**Canyon** A deep, narrow valley with steep sides.

**Capillaries** Tiny blood vessels that connect arteries to veins.

**Carnivore** An animal that eats only meat.

**Cells** The building blocks of almost all living organisms.

**Ceramic** Any object made from clay and hardened by heat.

**Chlorophyll** The green pigment in plants that helps them absorb sunlight for photosynthesis.

**Chromosomes** Packages of DNA found inside the nucleus of most cells.

**Colloid** A suspension of fine particles dispersed in a liquid.

**Colony** A group of organisms that live together.

**Condensation** The change of state from a gas to a liquid or a liquid to a solid.

**Continent** One of several large landmasses on Earth.

**Climate** The average weather conditions over a long period of time.

**Cloning** The process of producing genetically identical animals or plants.

**Communism** A political theory based on the common ownership of property.

**Crystal** A solid in which the atoms or molecules from which it is made are lined up in a regular pattern.

**Cubism** A style of art that shows a scene from several different points of view all at once.

**Deities** Gods and goddesses.

**Democracy** A system of government in which people elect their leaders.

**Diaphragm** A sheet of muscle that separates the lungs from the stomach.

**Dictator** A ruler who has absolute power.



**Distillation** Purifying a liquid by boiling it and then collecting the vapour.

**DNA** Deoxyribonucleic acid, the molecule that contains the blueprint for life.

**Echolocation** Seeing objects with sound by bouncing sound waves off them and detecting the reflections.

**Ecosystem** The community of organisms living in a particular area.

**Elytra** The hard forewings of beetles, earwigs, and some bugs.

**Embryo** Organism in the earliest stage of its development.

**Epiphyte** A plant that grows on another plant without damaging it.

**Evaporate** To change from a liquid to a gas.

**Evolution** The gradual development of living things over a long period of time.

**Exoskeleton** An external skeleton that supports and protects an animal's body.

**Extinct** No longer existing on Earth.

**Famine** Severe shortage of food, causing widespread hunger.

**Fertilization** When male and female sex cells unite to form an embryo.

**Fetus** The developing young of an animal before it is born.

**Filtration** The process of separating liquids from solids using a filter.

**Fossil fuels** Fuels formed from the remains of animals and plants that lived millions of years ago.

**Friction** The force that opposes movement.

**Fuel cell** A device like a battery that generates electricity from fuel and oxygen.

**Fungi** A large group of organisms, including mushrooms and yeasts, that feed by breaking down the bodies of other organisms.

**Galaxies** Groups of dust, gases, and stars that fill the universe.

**Genes** Stretches of DNA that contain the code needed to build a particular protein.

**Genome** The entire genetic makeup of an organism.

**Gills** Feathery structures on the bodies of amphibians and fish through which oxygen is absorbed from the water.

**Gourd** A large, fleshy fruit with a hard skin.

**Gravity** The force that pulls objects together.

**Greenhouse gases** Gases in Earth's atmosphere that trap heat from the Sun and warm the planet.

**Habitat** The place in which an animal or plant lives in nature.

**Herbivore** An animal that eats only plants.

**Hominids** The family of primates to which humans belong.

**Impressionism** A 19th-century style of art characterized by highly finished pieces of art that reflected the artist's response to what they saw.

**Inertia** The tendency of an object to remain at rest or in constant motion unless a force is applied to it.

**Invertebrate** An animal without a backbone.

**Joints** The meeting point of bones.

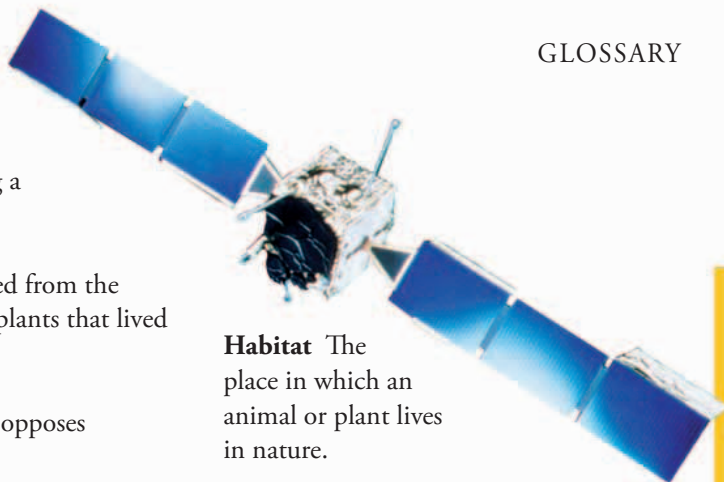
**Keratin** Tough protein found in animals' hair, nails, claws, hooves, horns, feathers, and scales.

**Lagoon** An enclosed body of water cut off from the sea by a reef or other landform.

**Lava** Molten rock flowing on the surface of Earth.

**Magma** Molten rock flowing under the surface of Earth.

**Mammals** Warm-blooded, furry animals that feed their young with milk.





**Mantle** Thick rocky layer of Earth between the crust and the core.

**Marsupial** A mammal that rears its young in a pouch or fold of skin, usually on its front.

**Matter** Anything that has mass and takes up space.

**Meditation** The process of emptying the mind of thoughts allowing the body to relax.

**Metamorphosis** A change in body form shown in animals such as insects and amphibians as they grow into adults.

**Microchip** The part of a computer made from silicon on which is etched electronic circuits.

**Migration** Moving from one place to another according to the seasons, usually to find food or to breed.

**Mineral** Solid material found in nature, usually as a crystal.

**Mirage** Optical illusion in which hot air distorts the reflection of an object.

**Monarchy** A ruling system in which a king or queen is the head of a country but does not necessarily govern it.

**Mosaic** An image created by using small pieces of colored glass or stone.

**Nanotubes** A sheet of carbon atoms rolled up into a tube with a diameter of 1 or 2 nanometers.

**National anthem** The official song sung in celebration of a particular country.

**Nebula** A gas cloud in space from which stars are born.

**Neurons** Nerve cells.

**Nutrients** Substances your body needs to live and grow.

**Omnivore** An animal that eats all kinds of food, both plant and meat.

**Opera** A dramatic work set to music.

**Orchestra** A group of musicians playing different types of instrument, from string and brass to woodwind and percussion.

**Organism** An individual member of a species.

**Ozone** Colorless gas that forms a layer in the Earth's atmosphere, absorbing some of the harmful ultraviolet radiation in sunlight.

**Parasite** An organism that lives on another organism and feeds off it.

**Peat** A rich type of soil formed from plants and their decaying remains.

**Periodic Table** A table that organizes all the known elements in order of increasing atomic number.

**Peristalsis** The muscle contraction in the walls of the esophagus and intestines that helps us swallow food.

**Persecution** The harrassment of an individual or group because of their race or beliefs.

**Pharaoh** The title given to the ancient kings of Egypt.

**Photosynthesis** The process by which plants make their own food using the energy from sunlight.

**Phylum** The biggest division within a kingdom of living things. A phylum is further divided into classes, orders, families, genera, and species.

**Phytoplankton** Tiny plants and algae that drift in the ocean and form a source of food for larger marine animals.

**Pigment** A substance that colors other materials.

**Pilgrim** Someone who travels to a sacred place as an act of religious devotion.

**Pixel** A tiny piece of information that makes up an image on a screen.

**Pointillism** A painting style that uses small dots of color.

**Pollinators** Animals that carry pollen from one flower to another.





**Pollutants** Any substance that contaminates the environment.

**Post mortem** The medical examination of a dead body to establish the cause of death.

**Poverty** Not having enough money to take care of basic needs such as food and clothing.

**Predator** An animal that hunts other animals.

**Prey** An animal that is hunted by other animals.

**Prophet** A person who receives divinely inspired revelations.

**Prosthetics** The branch of medicine that deals with the manufacture of artificial body parts.

**Pupating** A stage in an insect's life cycle when the larva breaks down inside a pupa and transforms into an adult.

**Reflection** When light bounces off a surface and then travels in a different direction.

**Refraction** When light bends as it travels from one substance to another.

**Refugee** A person who flees his or her own country to escape danger.

**Reptiles** Group of cold-blooded vertebrates that breathe air using lungs, such as snakes and lizards.

**Reservoir** A large artificial lake used to store water.

**Rodents** Mammals with large incisors used to gnaw hard substances.

**Ruminant** To regurgitate food and chew it again—sometimes called “chewing the cud.”

**Savanna** Tropical grassland with distinct wet and dry seasons.

**Scavengers** Organisms that feed on the remains of dead organisms.

**Shaman** A religious leader in some tribes who is thought to have the power to heal people.

**Species** A group of similar organisms that can breed and produce fertile offspring.

**Spores** The reproductive structures of some plants and fungi.

**Stem cell** A type of cell that can multiply and develop into different types of cell.

**Sublimation** When a solid changes directly into a gas (or gas into solid) without first becoming a liquid.

**Succulent** A plant such as a cactus that has fleshy tissue to conserve water.

**Sultan** The ruler of a Muslim country.

**Supernova** The bright explosion that occurs as a star collapses.

**Tendons** The strips of fibrous tissue that connect muscles to bones.

**Textiles** Cloth or fabric produced by weaving or knitting.

**Tissues** Collections of cells that work together to do the same job.

**Transgenic** A genetically modified organism that contains a gene from another species.

**Transpiration** The loss of water by evaporation from plant leaves and stems.

**Tricolor** A flag with three colored stripes.

**Tsunami** A large wave created by a volcano or earthquake, usually under the surface of the ocean.

**Veins** Blood vessels that carry oxygen-poor blood back to the heart.

**Velocity** Speed in a given direction.

**Venom** poisonous liquid produced by some animals, such as snakes and spiders.

**Vertebrate** An animal with a backbone.

**Viruses** Tiny particles that take over cells and reproduce inside them.

**Viscosity** The “thickness” of a fluid.

**Vizier** A high-ranking official in a Muslim government.





# Acknowledgments

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