

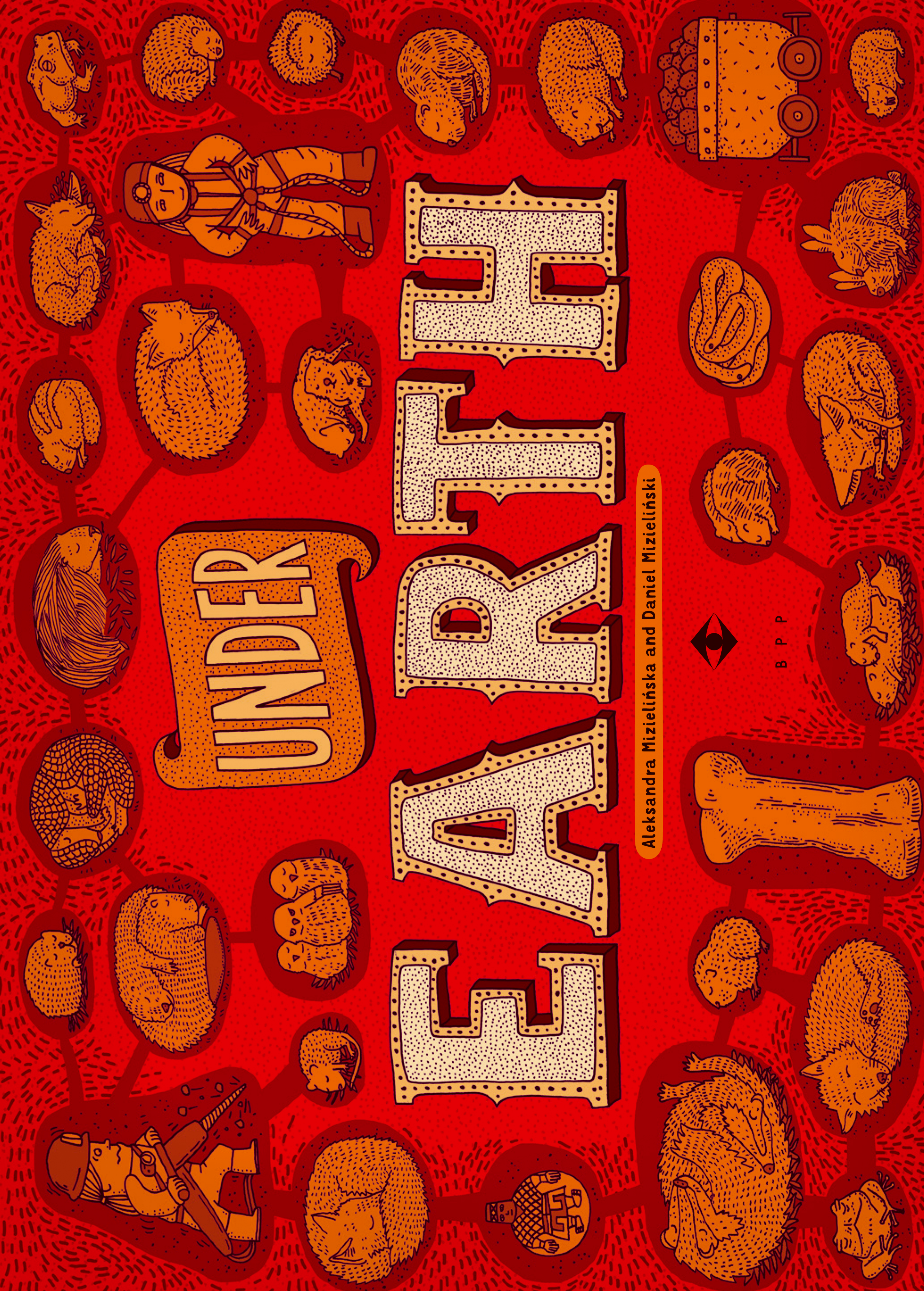
Aleksandra Mizelińska and Daniel Mizeliński



UNDERNUN

UNDER EARTH

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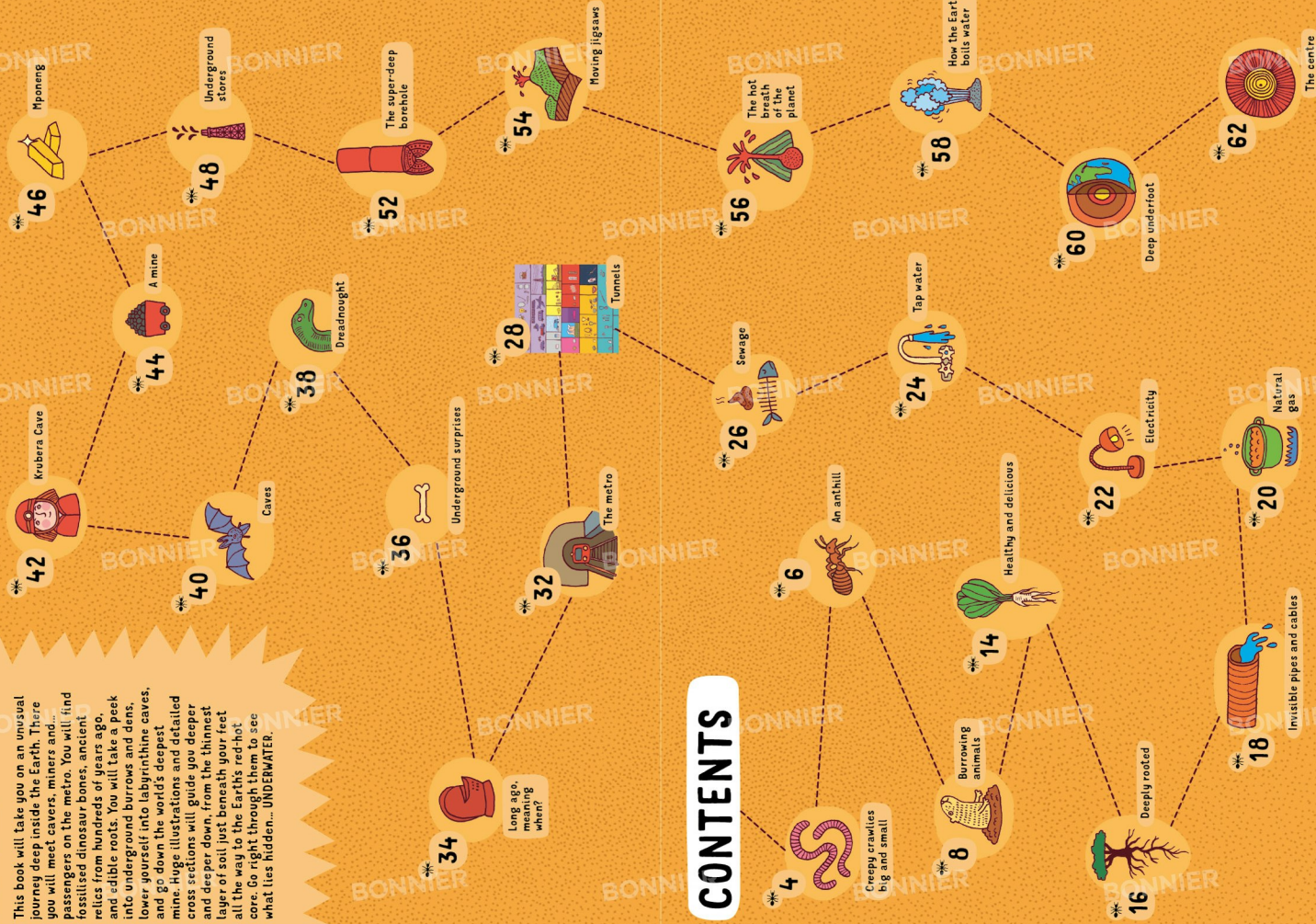
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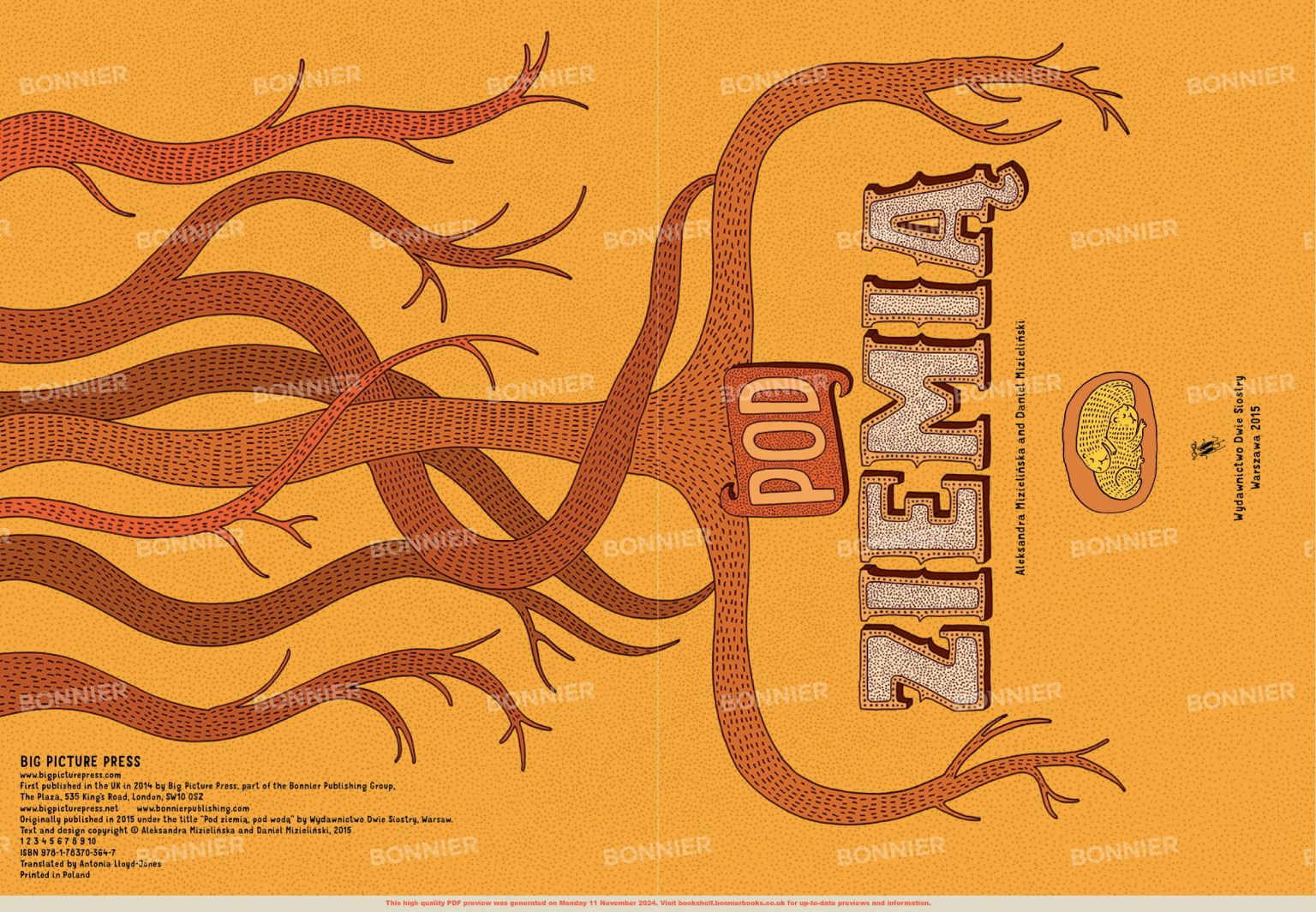


DISCOVER THE SECRETS OF THE UNDERGROUND WORLD

This book will take you on an unusual journey deep inside the Earth. There you will meet cavers, miners and... passengers on the metro. You will find fossilised dinosaur bones, ancient relics from hundreds of years ago, and edible roots. You will take a peek into underground burrows and dens, lower yourself into labyrinthine caves, and go down the world's deepest mine. Huge illustrations and detailed cross sections will guide you deeper and deeper down, from the thinnest layer of soil just beneath your feet all the way to the Earth's red-hot core. Go right through them to see what lies hidden... UNDERWATER.



CONTENTS



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**POD
ZIEMIA**

Aleksandra Mizielinska and Daniel Mizielinski



Wydawnictwo Dwie Siostry
Warszawa 2015

CREEPLY CRAWLIES BIG AND SMALL

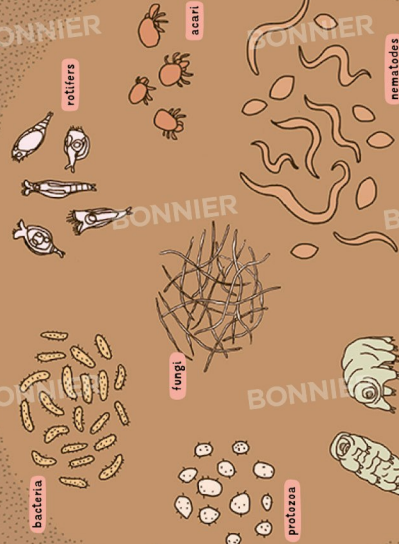
Just under the surface, only as far as 10cm away, there are swarming with living organisms. Most of them are so small that you need a microscope or a magnifying glass to see them.

They live in the soil, which consists of crumbled rocks and minerals, and the decomposing remains of plants and animals.

dung beetle

Dung beetles collect balls of horse or cow manure in the earth. They feed their larvae on these when their hatch out of their eggs.

dung beetle



bacteria

fungi

rotifers

acari

nematodes

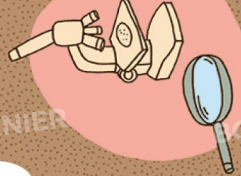
springtails

water bears

small eggs

beetle larvae

potworms



The large earth bumblebee lays its eggs in wax barrels that it builds underground.

The European bee wolf lays its eggs in an underground burrow.



earthworms

common earthworm or inborm

To see a giant earthworm, you have to go to Australia, where they live in caves in the ground. They can grow to as long as 3m.

The bee wolf parasyses bees with venom and drags them into its burrow. Once its larvae hatch, they feed on the bees.

Giant Gippsland earthworm



AN ANTHILL

The heap visible on the surface is just a small section of the anthill. The greater part of it is underground.



Common in Europe, red wood ants build anthills out of sand and pine needles. Some species live in chambers, which they bore underground chambers.

Black garden ants, found in cities, often build their nests entirely underground, without any heap above the surface.



A species of ant called *Messor acculeator*, which lives in Japan, acquires seeds from the ground. They sometimes go to depths of 4 m.

Ants can also live on trees, inside their stumps, or under stones. Some species do not build nests at all.

Depending on their species, ants feed on insects, plants, dead animals, plants, seeds, nectar or honeydew, a sweet substance secreted by aphids.

Many species gather supplies of food in their anthills.

seeds

Some species of ants from South and Central America live on fungi, including cultivating on chewed leaves inside the anthill.

Almost all the ants in the anthill are workers who look after the ant eggs and pupae, feed the larvae, look for food, defend the anthill, make it bigger and clean it.

1 The queen ant lays eggs continually, while the worker ants take care of her and provide her with food.

The queen is mother of the anthill and can live up to 30 years.



There can be one or many queens in a single anthill.

life cycle of the ant



pupa

adult worker ant



queen

The queens develop from the best nourished larvae.

The young queens and males have wings on their legs on making flight, during which the queen is fertilised.

Soon after, the males die, while the queens lose their wings and seek a site for a new nest, or are taken by the workers to the old anthill. When a queen founds a new nest, she digs it herself and looks after her eggs until the first workers develop from them and take on those duties.

egg

male

larva

pupa

adult worker ant

queen

2 The larvae hatch out of the eggs. They have no eyes or limbs, and all they do is eat what the worker ants provide in order to grow.

larvae

3 Once the larvae are big enough, they surround themselves with a cocoon and become pupae, from which the adult ants then hatch.

pupae

eggs

The worker ants dig new chambers.

In one of the chambers of the anthill, or just outside it, there is a place comparable to a graveyard. All the dead ants are carried there.

BURROWING ANIMALS

In almost every corner of the globe, a huge number of animals make use of underground hideouts. Burrows guarantee them shelter from predators, from cold or heat, and can also serve as larders. Some species spend their whole lives underground, while others just dig out a hole at birth and raise their young. Some dig complex systems of underground corridors, others make simple, shallow shelters, and some even use the hideouts built by other animals. Here is a selection of burrowing animals from various parts of the world.



great jerboa



steppe lemming



The southern African pocket gopher has many species of scorpion that dig burrows.



eastern chipmunk



pale kangaroo mouse



kingfisher



The eyes of the greater mole-rat are covered with skin. It uses its incisors to bore corridors.



gopher



large bamboo rat



weasel



Atlantic puffin

Puffins use their beaks and feet to dig burrows in which they lay their eggs.



meerkat



mountain beaver



fennec fox



burrowing owl



gopher tortoise

Like otters and beavers, muskrats situate the entrance to their burrows underwater.

The star-nosed mole has a snout that ends in two fleshy pea growths. She uses them to grab hold of food.



giant burrowing frog



water vole



tuco-tuco



European ground squirrel



fat-tailed gerbil



bank vole



field mouse



conuro



great gerbil



common rabbit



South African springhare



alpine marmot



Magellanic penguins dig burrows in the tip of South America, making their nests in burrows or under bushes.



The platypus, a venomous mammal from eastern Australia, digs its burrow on the banks of rivers and streams.



Liasis fuscus is a burrowing snake from Central America.



European otter

The African crested porcupine collects bones and other objects in its burrow such as stones or bits of wood. It gnaws them to trim its ever-growing incisors.



nine-banded armadillo

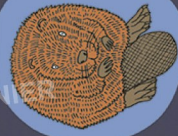


coypu

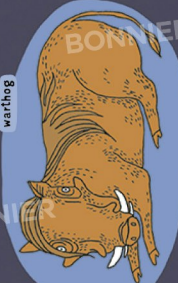


Tasmanian wombat

European beaver



Beavers live in burrows or lodges, which are shelters made of branches and silt.



warthog

the mole

Moles spend most of their life underground. They live alone and dig tunnels to search for their moles on their territory.

Mole tunnels can be hundreds of metres long.

A nest lined with leaves and dry grass is the mole's dormitory, and is also where the female raises her young.

winter dormitory

The mole uses the corridors it bores just under the ground's surface to look for food.

Moles live on earthworms and grubs.

In winter moles use deeper tunnels.

Moles have poor vision, but excellent hearing and a superb sense of smell.

Moles paralyze worms by biting off part of their heads, and then store them in the larder.

larder

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Moles paralyze worms by biting off part of their heads, and then store them in the larder.

larder

winter dormitory

-0.7 m

the naked mole-rat

Baby moles are born naked and blind. After two weeks they grow back hair, after which they lose their eyes for the first time, and after only five they leave the nest and their mother's tunnels.

Naked mole-rats live in eastern Africa.

They feed on tubers and roots.

Loose skin helps them to push through tunnels that are in the tight tunnels that they bore with their prominent incisors.

As a result, they always have a supply of fresh food that cannot escape from them.

Naked mole-rats can live for up to 30 years, which is a record for many rodents. In addition, they hardly appear to age at all, never suffer from cancer, cannot feel some kinds of pain and cope superbly with the limited oxygen in the burrow.

These characteristics fascinate scientists, who study them in order to find answers to the most important questions in medicine today.

-1 m

They form colonies that live in extensive systems of burrows. They almost never come to the surface.

Colonies can contain from a dozen to almost three hundred individuals.

Burrows can be from 1m to over 2m underground, and corridors may be several kilometres long.

nest

toilet

-1 m

the prairie dog

Prairie dogs live on the prairies of North America.

Prairie dogs warn each other of danger by emitting special squeaks. In this way, they are able to know back when a predator is approaching, how rapidly, and how far away it is.

A prairie dog that has its hind legs and its tail tucked and then in response others in the vicinity do the same. This is their way of making sure that all the other dogs in the group are on the alert.

Prairie dogs gather grass to line their nests.

The colonies are like huge cities, divided into districts and estates. Each of these estates – or systems of connecting burrows – is occupied by a single family.

The family usually consists of one male, several females and their young.

One of the chambers in the burrow is a designated toilet.

The largest colony of prairie dogs was identified more than 100 years ago in the state of Texas. It extended over an area of 65,000 km², which is as big as Lithuania, and it may have included as many as 400 million animals.

The young are born underground, and they get outside for the first time a few weeks later.

Prairie dog burrows reach depths of 2–3m underground.

-2 m

the badger

Small pits located near the sett are called 'toes'. These tell other animals about the presence of badgers and the borders of their territory.

bedroom

Several badger families can live in a single sett. It is usually extended by 1 year and passed from generation to generation.

Badger setts can be elaborate, with passages, corridors and chambers.

badger tracks

Badgers line their dens with grass, leaves and moss, so they will not have to sleep on the cold, damp earth.

The bedding is often changed, and sometimes the badgers also carry it out to the surface to air it. This is their way of taking care of hygiene.

Badger setts are on average from 1–2m deep.

Badgers hibernate.

-1.5m

Badgers are nocturnal animals. They spend all day in the sett and at night they go out in search of food.

The sett is kept immaculately clean. The animals make sure there are no food remains or faeces inside it, and carry all waste matter outside.

the red fox

main entrance into the den

Foxes hunt at dawn, at dusk, and during the night.

They are active all year round and do not hibernate.

fox tracks



Foxes usually live on their own, sometimes in small family packs. They pair up to raise their young.

Foxes do not dig large, complicated dens. For most of the year they go in and out of their own or take advantage of other animals' unused burrows, such as badger setts or rabbit warrens. A fox will sometimes move in with a badger too, and then each animal occupies a different chamber.

They only seek a deeper, safer hideout when they are going to give birth. They will sometimes use the burrows of other animals' unused burrows, such as badger setts or rabbit warrens. A fox will sometimes move in with a badger too, and then each animal occupies a different chamber.

food remains

They mainly feed on mice and other rodents, but they can also eat frogs, birds, insects, earthworms, and fruit.

They avoid eating shrews and moles because these creatures secrete stinky substances that taste unbearable to most predators.

Fox cubs are born blind and deaf. At birth they do not look like their parents, but are grey, short, round-faced, and they are unable to suck their mothers' milk.

After six weeks their fur becomes red.

Burrows have an emergency entrance that is used in case of danger.

If foxes hunt more than they can eat, they save the extra food for later. That is why they hunt even when they are full.

fox stores

Fox dens can extend to more than 2m underground.

-2m

HEALTHY AND DELICIOUS

Edible and medicinal roots, rhizomes, tubers and bulbs

Many plants store nutritious substances in special underground organs: storage roots, tubers, rhizomes or bulbs. How do we tell them apart? Storage roots are usually thick, fibrous stems, but generally they are fat and fleshy. Rhizomes are thickened underground stems, usually growing horizontally. Bulbs consist mainly of tightly packed layers of scaly leaves, with thin rootlets growing from their lower end.



turnip
Turnips were cultivated in the ancient world, and maybe even in pre-historic times.

swede
Used in many dishes even in pre-historic times.

parsnip
In Europe in the past its sweet root was used instead of sugar.

carrot
Carrots come in several different colours, from orange to dark red to white.

horseradish
Wasabi

onion
Common onions are available in three colour varieties: brown, red and white.

garlic
In the Middle Ages, people believed garlic protected them from scurvy and vampires.

finger root
Used in Spain to make a delicacy called *horchata de chufa*.



radish

daikon

black Spanish radish

sugar beet
Sugar is obtained from this.

mangelwurzel
Grown as fodder for animals.



black salsify
In the past it was used as a remedy for snake bites.

greater burdock

Has medicinal properties.



common salsify



Indian lotus
Lotus rhizomes are used in many Asian dishes.

water chestnut
Despite its name it is not a nut, but an aquatic vegetable.

skirret
This was popular in Tudor China and Japan.

yam
The inside of the tuber is an intense purple colour.

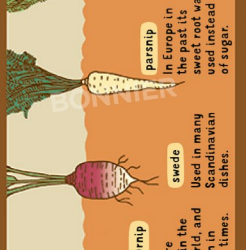
purple yam
The inside of the tuber is an intense purple colour.

zamkand
A vegetable grown in Asia. The tuber is used to make a kind of flour and jelly.



Chinese artichoke
Used as an ingredient in Japanese New Year dishes.

ludzu
Used in Japanese kuzumochi cakes.



swede
Used in many dishes even in pre-historic times.

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Used in Spain to make a delicacy called *horchata de chufa*.

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white yam
These are grown in Africa.

ensete
One of Ethiopia's major cultivated plants.

prairie turnip
This grows on the North American prairies.

potato bean
Used in the North American prairies.

common camas
Eaten by North American Indians then.

Jerusalem artichoke
It is often used in Mexican cooking.

arrowroot
A vegetable grown in tropical places worldwide.

cassava
An important source of food in tropical worldwide.



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arracacha
These come from the Andes Mountains in South America.

moca
These come from the Andes Mountains in South America.

potato
These come from the Andes Mountains in South America.

yuca
Often inaccurately called a yam.

four o'clock
Often inaccurately called a yam.

bulb onion
A medicinal plant highly valued in China for thousands of years.

yam daisy
Traditional foods of the indigenous Aboriginal people of Australia.

bush potato
Traditional foods of the indigenous Aboriginal people of Australia.



turmeric
They are used as spices.

ginger root
They are used as spices.

galangal
This helps to cure a cough.

marshmallow
This has medicinal properties.

lovage
This has medicinal properties.

bush carrot
A medicinal plant highly valued in China for thousands of years.

bulb onion
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Traditional foods of the indigenous Aboriginal people of Australia.

Tree roots rarely run 2m into the ground, and most of them are much shallower than this at just half a metre under the surface.

Rocks grow in soil which has hard rocks underneath it. High in the mountains, the trees can only grow out to the sides just under the ground surface.

Thanks to their roots, plants are solidly secured in the ground. They use their roots to draw water and minerals from the soil.

The depth of roots depends on the amount of water and many other factors.

If water and minerals are accessible in the layer of soil just below the surface (and that is usually where they are most plentiful), roots do not need to grow deeper.

Tree roots often spread over a far wider area than the top of the tree.



Pando
In the state of Utah in the USA there is a colony of trees called Pando, which covers an area of 0.4km², and which is one single, immense organism. 80,000 years of age, scientists estimate that there are more than 40,000 aspen trees growing there all share the same root.



umbrella thorn 35m
This species of tree grows in savannah and arid areas in Africa where there is very little rainfall. It can survive in places where no other trees will grow.



eucalyptus 60m
Most eucalyptuses grow in Australia. These fast-growing trees are capable of living in very tough conditions. They can survive droughts and fires.



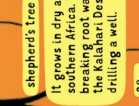
one-seed juniper 61m
This only grows in desert areas in the southern United States.



camel thorn 60m
This grows in the Kalahari Desert in southern Africa.



mesquite 85m
The longest known root of this tree was discovered in a mine in Arizona in the United States.



shepherd's tree 68m
It grows in dry areas of southern Africa. The record-breaking root was found in the Kalahari Desert while drilling a well.

RECORD HOLDERS

The roots that reach deepest are of plants that grow in deserts. The plants send them deeper and deeper underground in search of water.

Most of the known cases of the deepest growing roots have been observed in mines and construction pits.

Nobody knows if there are plants on Earth whose roots reach even deeper, but the possibility cannot be excluded. Perhaps the real record holders are growing quietly somewhere, not bothered by anyone.

INVISIBLE PIPES AND CABLES

In the ground under cities, pipes and cables stretch for kilometres. But do they all do the same thing, and where? You'll find out on the next few pages.

The pipes and cables are located from one to two metres underground, or even deeper. To find out what they do, you have to dig through them, what is on the surface, above them and in the ground around them, and on how deep down the earth freezes.

pipe carrying natural gas (see pages **20-21**)



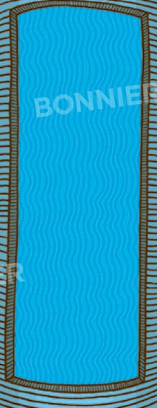
electricity cable (see pages **22-23**)



Pipe carrying hot water for heating (see pages **24-25**)



Pipe carrying cold water for use in the kitchen and bathroom (see pages **24-25**)



sewage pipe (see pages **26-27**)



NATURAL GAS

What is it used for?

To heat farm buildings for animals

To heat hot-houses

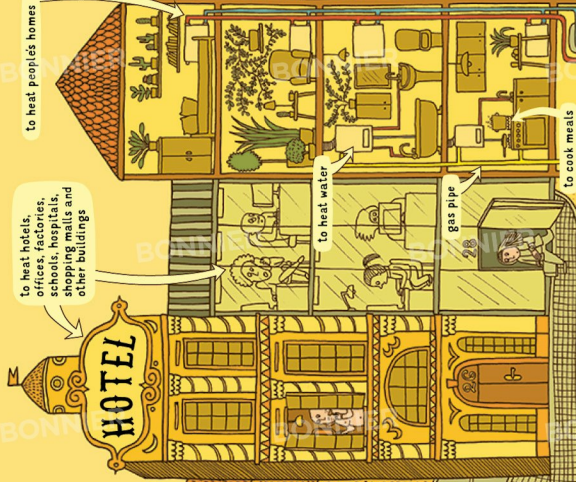
To manufacture plastic, paint, glue, cleaning products and many other things

To produce artificial fertilisers

as fuel for vehicles

To heat hotels, offices, factories, schools, hospitals, shopping malls and other buildings

To heat peoples homes



Natural gas has many more uses, and so it is used in many other ways. It can be used to have little or no gas deposits buy it from others. The largest supplies of natural gas are extracted by Russia and the United States.

In cities gas is supplied to buildings through pipes that run underground.

Gas burns in the boiler and heats the water.

combustion fumes

to cook meals

to heat water

gas pipe

air

Where does natural gas come from?

Gas is extracted from underground. It was produced there millions of years ago from the remains of tiny organisms. Once extracted, the gas is transported to consumers via a network of pipes, or pipelines.

drilling rig

Natural gas deposits lie very deep in the ground. To reach them, you have to drill down to the deposit. When the hole reaches the deposit, the gas escapes to the surface, because it is trapped in the earth under very high pressure.

Gas can be sent by pipeline – even thousands of kilometres.

How is natural gas kept?

Not all the gas that is extracted is used at once. Some of it is stored, so that it can be used when the need arises (for example for heating during a cold winter).

After being cooled to -162°C , natural gas changes into a liquid and occupies far less space. It is then stored in this particular form in underground tanks.

Gas is usually stored underground in empty spaces surrounded by impermeable rocks. For example, the salt caverns produced by extracting rock salt are suitable for storing gas.

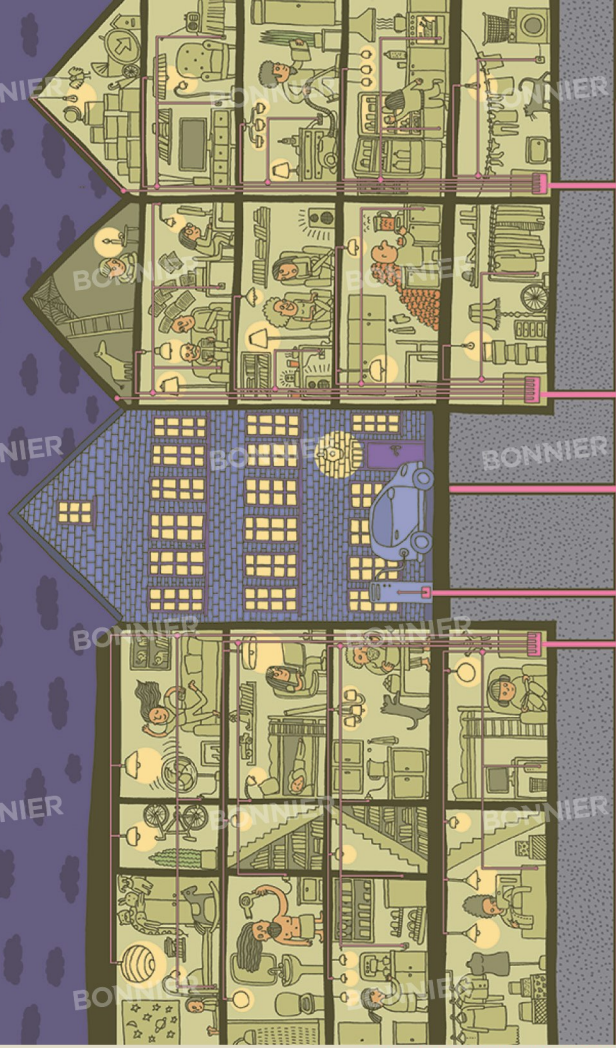
Wells for extracting natural gas go down to depths of as much as 6000m

Some layers of rock that accumulate water are also suitable for storing natural gas.

rock that is impermeable to natural gas

When the entire deposit of natural gas has been extracted, the empty space it leaves behind can be used as an underground gas store.

natural gas



5 Before the electricity reaches buildings and homes, it is lowered in transformers.

6 The high-tension current is sent out via power lines.

transformer

How is electricity made?

Electricity is produced at power stations. Fuel of the world's electricity is produced at power stations (the kind where black or brown coal is burned) than any other kind. Increasingly often animal waste materials, such as straw or wood cuttings, are burned at them too.

1 fuel – either coal or biomass

2 The fuel is ground to dust and fed into the boiler.

3 The fuel is burned inside the boiler. This heats up the water circulating in the pipes, changing it into steam.

A thermal power station generates electricity by heating water to create steam, which turns a turbine. Some stations also generate hot water for heating.

4 steam

500°C

turbine

5 After setting the turbine in motion, the steam cools and condenses.

6 The turbine starts up the generator, which produces an electric current.

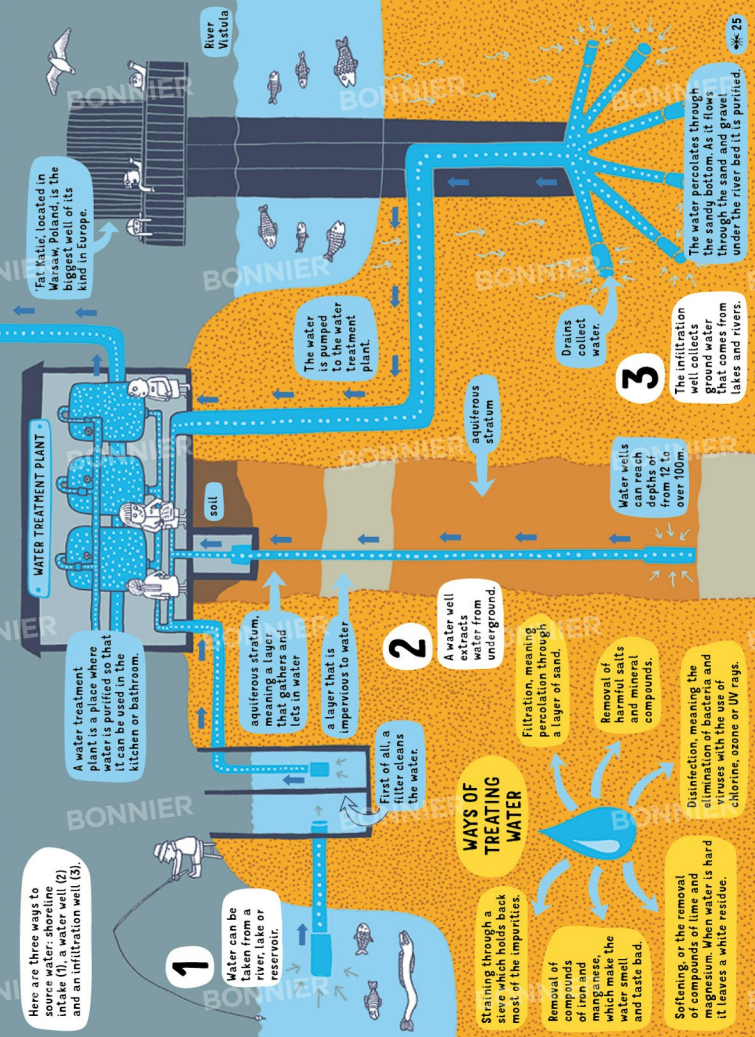
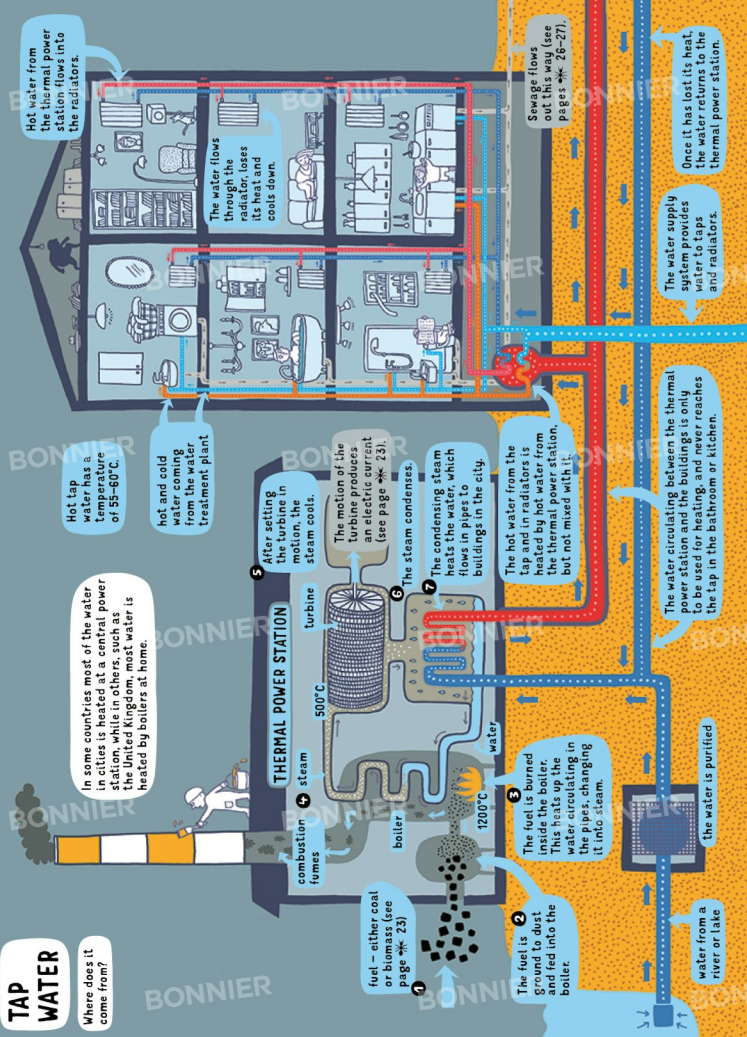
7 The current is transferred to the next producer by a transformer, which increases its tension so that it can be transferred over great distances.

8 See page 24, to find out what happens to the electricity produced by a thermal power station.

There are many different kinds of power station. Each of them uses a different kind of fuel. In nuclear power stations it is the energy obtained as a result of splitting the nuclei of atoms. In wind power stations it is the energy of the wind. There are also solar, hydro, gas and geothermal power stations – the last of these uses heat from the Earth's interior.

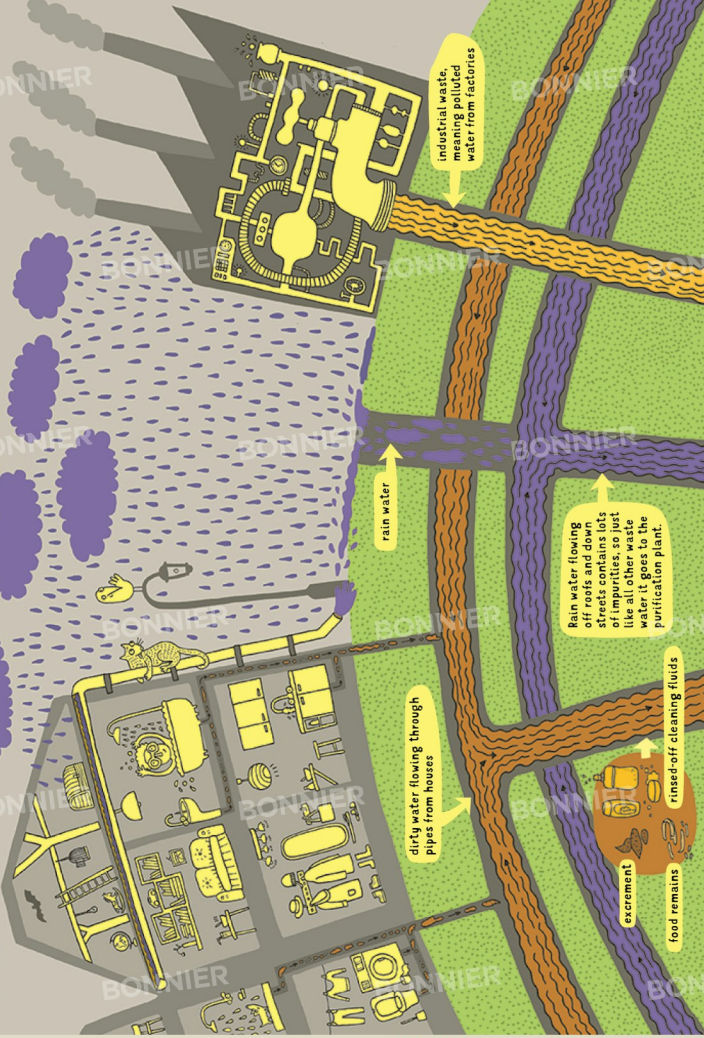
TAP WATER

Where does it come from?



SEWAGE

is dirty water full of the remains of food, excrement and chemical substances harmful to the environment. It is carried away from houses, factories and streets via a system of underground pipes and sewers, known as the sewage system.



Industrial waste, meaning polluted water from factories

rain water

dirty water flowing through pipes from houses

Rain water flowing off roofs and down streets contains lots of dirt and other stuff like all other waste water. It goes to the purification plant.

excrement
food remains
rinsed-off cleaning fluids

The screenings are transported to the rubbish dump.

1 Grilles hold back the screenings, which are the largest impurities, such as food waste.

Sand is transported from the rubbish dump.

With the help of the sandbox the sand is removed from the waste water.

2 When the waste water flows through the sandbox, the sand falls to the bottom.

5 removal of residues

secondary settling tank

Suspensions and residues are separated from the water and collected at the bottom of the tank.

* How does a settling tank work?

clean water

suspensions and residues

4 The bacteria living in the bioreactor 'feed' on carbon, nitrogen and phosphorus, removing them from the water.

Residues collected while purifying water are dried and thickened. They still have uses – as fertilizer for instance.

3 removal of suspension

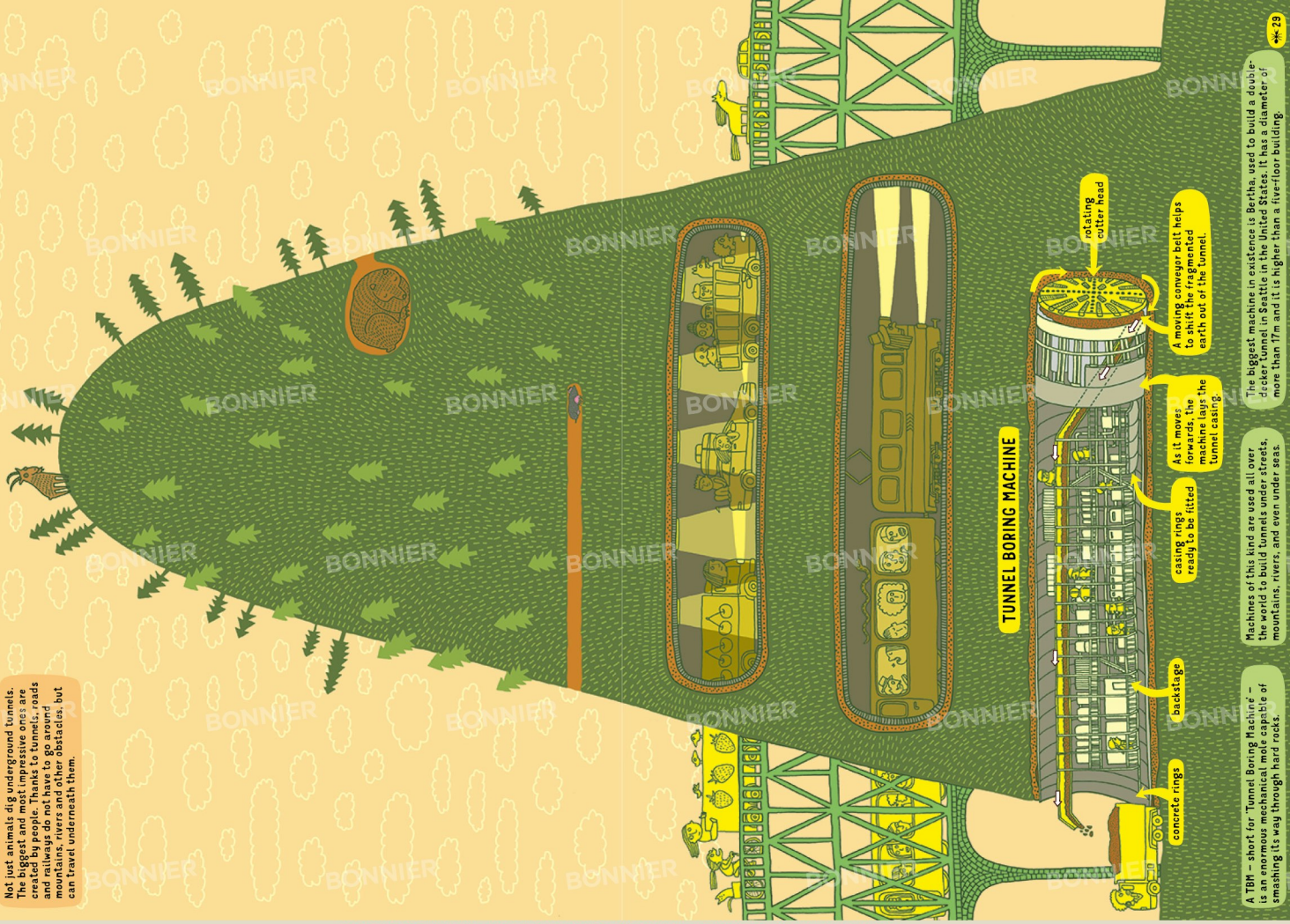
primary settling tank

suspension

Suspension is like a soup full of bits of vegetables floating in it.

TUNNELS

Not just animals dig underground tunnels. The biggest and most impressive ones are created by people. Thanks to tunnels, roads and railways do not have to go around mountains, rivers and other obstacles, but can travel underneath them.



TUNNEL BORING MACHINE

concrete rings

backstage

casing rings ready to be fitted

As it moves forwards, the machine lays the tunnel casing

rotating cutter head

A moving conveyor belt helps to shift the fragmented earth out of the tunnel.

A TBM – short for ‘Tunnel Boring Machine’ – is an enormous mechanical maul capable of smashing its way through hard rocks.

Machines of this kind are used all over the world to build tunnels under streets, mountains, rivers, and even under seas.

The biggest machine in existence is Bertha, used to build a double-decker tunnel in Seattle in the United States. It has a diameter of more than 7m and it is higher than a five-floor building.

Gottard Base Tunnel

Switzerland

The longest rail tunnel in the world, its construction took nearly 20 years.

The Alps

Aar Massif

Saint-Gotthard Massif

57km
tunnel length

Both passenger and freight trains will drive through it, as well as trains that carry entire lorries and their cargo. The tunnel will shorten the travelling time between cities in Switzerland, Italy and Germany, and fewer vehicles will drive along the Alpine roads.

Seikan Tunnel

Japan

53.85km
tunnel length

city of
Aburahi

city of
Hakodate

Hokkaido island

Honshu island

Tsugaru Strait

140m

100m

240m

To travel from Honshu, the largest Japanese island, to neighbouring Hokkaido, you only have to go on a half-hour journey through the 54km tunnel running partly under the seabed.

The Seikan is the deepest rail tunnel in the world.

Plans to build the tunnel began in the mid-20th century, when flying by plane was not as common as it is today, and crossing the Tsugaru Strait by ferry was dangerous because of frequent typhoons.

Lærdal Tunnel

Norway

24.51km
tunnel length



In Norway, in the winter many roads in the mountains are covered with ice and buried under snow. And so on the stretch between two large cities – Bergen and Oslø – a tunnel was built. It was built, which allows travellers to reach their destination faster and more safely.

To make the 26-minute journey through the tunnel less monotonous, you can stop on the way at one of the three caves illuminated by blue-and-yellow light.

CAVE

Bergen

Oslø

The Warsaw metro

Poland

Palace of Culture and Sciences

The deepest station is Nowy Świat-University.

23m

the Warsaw Mermaid

Swiętokrzyski Bridge

National Stadium

To build the new, second line of the Warsaw metro, four boring machines were used. Each one was 97m long, weighed 615 tons and bored the tunnels using a disc with a diameter of almost 6.5m.

The world's longest metro tunnel is in the Chinese city of Changsha. It is more than 60km long.

THE METRO

Most metros, or underground urban railways, run from 10–100m below street level.

Every year, the number of cities in the world where you can travel by metro increases. In 2016, there were 148.

LONDON

Great Britain

The London Underground (the Tube) is not the deepest, but the oldest metro system in the world.

The New York subway has the most stations. A total of 468.

3 000 000 000

The largest number of passengers is 3 billion annually – travel on Tokyo's metro. That is equal to every citizen of Europe making a journey four times a year.

The shortest metro line only has 10 stations, and is less than 4km long. It is in Taormina, a city on the Italian island of Sicily.

There are many cities where the metro operates automatically with no train drivers. The longest line like this is almost 79km long, and is in Dubai.

The first London Underground stations, including Baker Street, were opened more than 150 years ago, in 1863.

The deepest London Underground station is Hampstead. It is at a depth of 56.5m.

PORTLAND

Oregon, United States

Washington Park is not a subway station, but a light rail station. But it is the deepest underground station in the whole of America.

The Robertson Tunnel, in which the station is located, is almost 5km long and passes under hills to the west of the city.

SAINT PETERSBURG

Russia

There are two extremely deep metro stations in Russia: Admiralteyskaya in Saint Petersburg (106m deep), and Park Pobedy in Moscow (104m deep).

Адмиралтейская Станция

KIEV

Ukraine

Arsenalna Station is the deepest station in the world.

It had to be built deep down because of the location of the River Dnieper.

To reach the station, the citizens of Kiev ride escalators deep into the ground, which is equivalent to more than 38 floors.

АРСЕНАЛЬНА

PYONGYANG

North Korea

The metro system in the capital of North Korea is one of the world's deepest.



천리마선

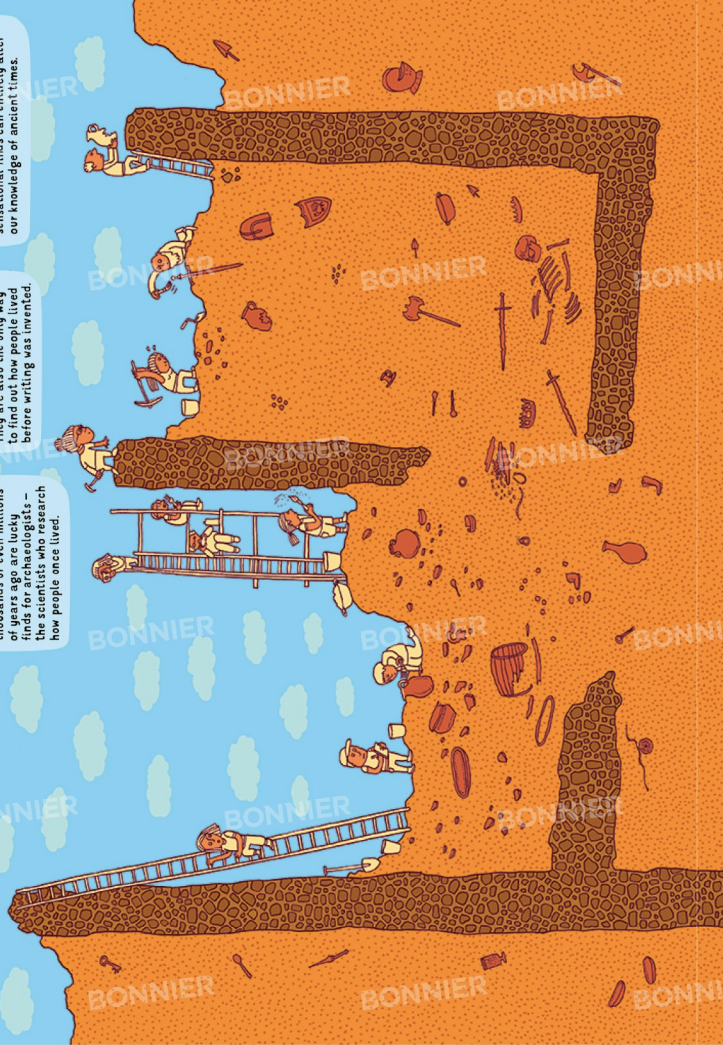
about
-110m

LONG AGO, MEANING WHEN?

Hidden in the ground, the remains of old buildings and objects from hundreds, thousands or even millions of years ago are lucky finds for archaeologists — the people who search for what people once lived.

Archaeological finds help us to understand the times described in ancient texts. They are also the only way to find out how people lived before writing was invented.

Sometimes valuable relics are discovered by chance in places where nobody expected them to be. The most sensational finds can entirely alter our knowledge of ancient times.



HOW DO WE DETERMINE THE AGE OF AN OBJECT?

Scientists have various ways of doing this, depending on the sort of material they are dealing with.

FINDS THAT WERE ONCE PART OF A LIVING ORGANISM — RADIOCARBON DATING

Their age is determined by finding out how much radioactive carbon they contain. The amount of carbon in every living organism, and from the moment of death its quantity decreases. Testing to see how much is left allows us to estimate when the person, animal or plant was alive. This is how items including bones, wood, skin, fabric or paper are dated.

BONES

To determine their age, we measure their fluoride content. This increases with the passage of time.

CERAMICS AND BRICKS

The date when they were fired is proved by the arrangement of particles of metal contained in them, which varies depending on the Earth's magnetic field at the time.

WOOD

Examining tree rings allows us to estimate when a piece of wood was still part of a living tree.

ALL EXCAVATED FINDS

They can be dated on the basis of the depth at which they were found. The greater the depth, the older the object.

FINDS FROM VARIOUS PARTS OF THE WORLD



Lanse aux Headows is a Viking longship founded over 1000 years ago. It is proof that the Vikings reached America long before Christopher Columbus.



The stone figure of the Venus of Willendorf is 11cm high and over 27,000 years old.



The Terracotta Army consists of 500,000 figures of soldiers and horses that were placed in the tomb of the first emperor of China over 2,220 years ago.

Canada

Australia

China

Ethiopia

Australia



These human footprints in clay have survived under the desert for over 20,000 years.



The Sun Stone was carved by the Aztecs over 530 years ago.



This clay vessel was placed in the royal tomb known as El Castillo de Huarmey 1200 years ago.



The oldest excavated fossil skeletons of creatures related to humans are 4.4 million and 3.2 million years old. Scientists named them Ardi and Lucy.



The oldest known stone tools used by our ancestors date from over 3.5 million years ago.



UNDERGROUND SURPRISES

Evidence of life in the past is sought underground not just by archaeologists (see pages 34–35), but also by palaeontologists. They research fossils, which are the remains of plants and animals that have been preserved in rocks.

The most famous creatures that we know about thanks to fossils are the dinosaurs. They died out over 60 million years before humans first appeared.

HOW ARE FOSSILS FORMED?

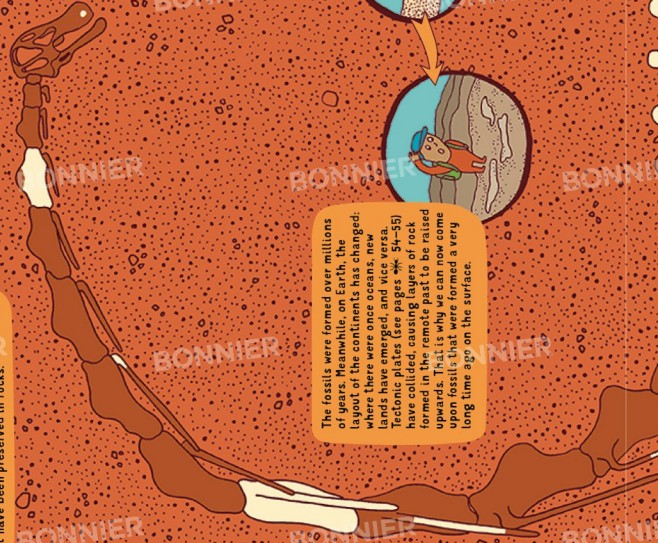
The outer crust consists mainly of sedimentary rocks. These are rocks that are formed from the settling of tiny particles, such as sand or silt, carried by water or the wind.

Over millions of years, these loose deposits form dense rocks. The deeper the layer, the older it is.

The fossils were formed over millions of years. Meanwhile, on Earth, the layout of the continents has changed, the land has emerged, and seas versus tectonic plates (see pages 54–55) have collided, causing layers of rock formed in the remote past to be raised upwards. That is why we can now come upon fossils that were formed a very long time ago on the surface.

When a dead organism (an animal or plant) is covered by rock, its soft parts decompose. The hard parts – usually animal bones or shells – are preserved.

Bones have the structure of a sponge – they are full of microscopic holes. These tiny holes gradually fill with particles of rock carried by water flowing underground. In this way the hard parts of the organism change into rocks, and so fossils are formed.



Other kinds of fossil



fossilised shell



imprint of a plant



dinosaur tracks



imprint of a fish



fossilised tree trunk

skeleton of the dinosaur *Tyrannosaurus rex* (see pages 36–39)

The bones that were found are marked in white.

DREADNOUGHT

The complete dinosaur skeletons that we admire in museums are usually not real, both stunning and complete finds are extremely rare.

Generally the palaeontologists (see page 36-37) find just a few bones, which, after detailed analysis and in combination with other finds, allow them to guess what the creature looked like.

For this reason the discovery of the dinosaur *Dreadnoughtus schrani* by American palaeontologist Kenneth Carpenter was unique – to date it is the most complete titanosaur skeleton ever to be found.



Titanosaurs are a group of dinosaurs that include the biggest land creatures ever to have lived on Earth. The remains of their continent-sized *Dreadnoughtus schrani* was one of the biggest titanosaurs.

See which bones were found on pages 36-37

To the untrained eye, the items found by palaeontologists often look no different from ordinary stones. But the experts know that every fossil conceals its own fascinating history.

Scientists can estimate the age of the fossils that have been preserved, and that tells them how long ago the dinosaur lived.

The structure of the skeleton allows them to establish how the creature moved about.

Tendons are visible on fossilised bones of the places where muscles were attached. This makes it possible to reconstruct the appearance of the dinosaur. Knowledge of the anatomy of contemporary animals helps greatly – certain things work in a similar way to millions of years ago.

The colour of dinosaurs still remains a mystery.

WHAT DO FOSSILS TELL US ABOUT THE DINOSAURS?



Fossilised excrement provides information about what dinosaurs fed on.

The weight and size of the creature, and how quickly it moved can be estimated by examining fossilised footprints.

We can imagine what a dinosaur's skin was like on the basis of imprints in the rock. Unfortunately imprints of dinosaur skin are very rarely found.



Cells were preserved in the remains of the today birds whose feathers. As a result we know that it was covered with red-and-white feathers.

A curious exception is a *Sinosauropteryx* whose remains were found in China.

This is what *Dreadnoughtus schrani* may have looked like.

The Latin name *Dreadnoughtus schrani* is based on the English word 'dreadnought' meaning 'fearless'.

SOUTH AMERICA



The specimen whose skeleton was found in Argentina measured 26m long and weighed almost 60 tons. The scientists believe that when it died it was not yet a mature, fully grown individual.

The remains of *Dreadnoughtus schrani* were found here.

CAVES

The world's deepest known cave is Krubera Cave in Georgia, in the Caucasus (see pages 46-47-48). It has been explored to a depth of 2197m.

The longest known cave is the Mammoth Cave in Kentucky, USA. The entire length of its corridors is more than 627km.

Scientific research of caves is done by a speleologist. He or she establishes how the cave passages are like inside it and what animals and plants live there.

A potholer is someone who enjoys discovering new passages in caves, goes climbing and does themed dives in underground lakes.

Speleologists are often potholers as well.

Caves are naturally formed spaces within rock. The most numerous and largest are solution caves, which is the name for caves that have been bored out of the rock by water flowing for thousands or even millions of years.

Thanks to water dripping from the ceiling in solution caves, stunning dripstone rocks are formed: stalactites, stalagmites and dripstone drapery.

Caves are the home of temporary shelter for bats, crickets, spiders, snails, fish and many other animals. There are probably species among them that have not yet been discovered.

stalagmite

dripstone drapery

stalagmite

Townsend's big-eared bat lives in North America.

The orb-weaver cave spider can be found in many countries in Europe and Asia.

The shining larvae of the New Zealand glow-worm light up New Zealand's caves. Their glow, produced by bacteria, lures small insects that the larvae feed on.

A vertical corridor in a cave is called a well or a chimney, depending whether it is explored from top to bottom or vice versa.

A siphon is a corridor in a cave that is full of water up to the ceiling.

The blind cave tetrafish lives in caves in Mexico.

The Texas blind salamander is only found in one place in the world – inside some caves in a small area of Texas in the USA. It lives in the dark in the dark it does not need eyes and is totally blind.

The proteus is a salamander found in the underground waters of Europe's Dinaric Alps. It is blind, but has a good sense of smell and hearing.

KRUBERA CAVE

This is the only cave whose depth is known to exceed 2000m. It is named after Russian geographer Alexander Kruber.



It is cold, wet and totally dark inside Krubera Cave, and the water flowing down the mountain can make it very noisy.



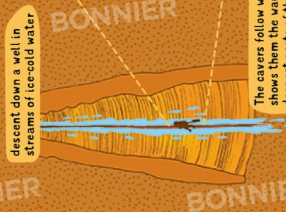
An expedition member ready to go into the cave.

During an expedition, cavers carry tons of supplies and equipment into the cave.



The leader of very many expeditions to Krubera Cave is the Ukrainian speleologist Alexander Klimchuk.

Employing such deep caves is team work. Some of the expeditions include more than 50 members.



descent down a well in streams of ice-cold water

The cavers follow water, which shows them the way to the deepest parts of the cave.

2

January 2001
An Alkhasian expedition descended to a record depth of 1740m. This allowed Krubera Cave to be acknowledged as the world's deepest known cave, and took the title (later broken by the Russian team in the Alps (-1632m).

4

10 August 2012
To break the record for depth, speleologist Gennady Semakin spent an hour diving in a siphon, because the final known section of the cave is filled with water.

After reaching a depth of 2197m, it took the expedition members 2 weeks to climb back to the surface with all their equipment.

The entrance to the cave is at a height of 2256m above sea level.

1

0°C in summer
This is the point reached by the first explorers.

cross-section of the cave

The cave was discovered by Georgian scientists in the 1860s. By the 1930s, the cave was being deeper and deeper, proved to the researchers how very deep it is.

2°C



Eiffel Tower (Paris) 324m

Buri Khalifa (Dubai)



a meal at a depth of 1960m.

On longer expeditions the cavers pitch camp to eat, sleep and rest. Sometimes they spend as long as three weeks underground without a break.



2km of rope weighs 100kg. When wet, it becomes three times heavier.

3

October 2004
Looking for new passages, cavers came upon a corridor that they named 'The Way to the Dream'.



The corridor is 90m long and is so narrow that you cannot move on all fours inside it - you have to crawl on your stomach.

Thanks to this passage, a depth of 2000m was achieved for the first time in history. The cavers named the passage 'Game Over'.

4°C

The Way to the Dream' corridor

Plutomurus oribolaganeensis



It has no eyes, lives in total darkness, and has a long and decomposing matter.

actual size

4mm

This is the deepest known land animal. It has a body length at depth of 1980m.



6°C

'Game Over' chamber

-2000m

A MINE

Mines are where useful mineral resources (see pages 44-51) are extracted from underground.

Deposits that lie at a shallow depth are extracted from open-cast mines, and ones that lie deep down are extracted from underground mines, like this bituminous coal mine.

winding tower

hoist

extracted bituminous coal

shaft

The shaft is a vertical passage in the mine, which the miners use to travel underground and to transport coal and extracted raw materials.

This shaft is only for carrying coal up to the surface.

One of the pieces of equipment used to transport coal and other materials is the bucket conveyor.

empty buckets

In the past the miners used pickaxes to extract coal.

Now they have machines, to help them do the work, such as very powerful mining drills.

The loaded buckets travel up to the surface.

tunnel boring machine

To break up the rocks they use explosives, such as dynamite.

shaft

lift

hoist

shaft

shaft

In large, modern mines most of the work is done by powerful machines capable of extracting thousands of tons of coal per day.

The miners travel to the more remote parts of the mine by underground train.

bituminous coal

conveyor belt

The vehicle is equipped with a moving belt that, once activated, carries the coal forwards.

A roadheader crumbles the coal by drilling a corridor into it, known as a drift.

A longwall shearer can extract 50 tons of coal per minute.

longwall shearer

Supports hold up the roof.

A moving conveyor belt carries the coal to the shaft.

The machine moves along the wall, crumbling coal onto the moving conveyor belt.

MPONENG

The world's deepest mine is in South Africa. Its name, Mponeng, is an Xhosa word in the African Sotho language. Gold is extracted there, and the depth of the mine is 3620m below ground.



entrance to the mine

The steel ropes are 6cm thick. Their condition is regularly checked.



lift

The lift reaches a dizzying speed of 60km per hour. As many as 120 people can fit inside it.



The lifts in the mine's deepest shafts go down to a depth of almost 3.5km below the ground surface.

The miners check special sensors to make sure there is no methane in the mine – a gas that combined with air can explode and cause a fire.



Working in the mine is very dangerous. Fires and earthquakes can occur at any time. The miners work hard in tunnels. It is a very long way back to the surface.



Pillars known as pit props hold up the ceiling of the underground corridors.

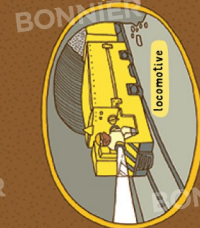


tunnels

Some corridors are so low that it is impossible to stand up.



The mine has its own inhabitants – rats and cockroaches.



locomotive

The gold ore and rocks extracted while boring the tunnels are transported by underground trains.



Gold ore



All of the gold extracted at the mine comes from a narrow strip of ore running deeper and deeper underground.



The temperature at the bottom of the mine is 65°C. The air in the corridors is cooled to 18°C to make it possible to work in such depths.

The journey from the surface to the deepest parts of the mine takes an hour and a half.



The present depth of the mine is not final – there are plans to make it deeper.

-3620m

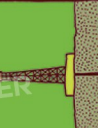
UNDERGROUND STORES

Mines and wells allow us to gain access to natural resources accumulated underground. Valuable raw materials are found there that can be processed to produce useful objects or energy. Here are some of them.

natural gas

See pages 48-50-21.

It is used as a fuel and to produce substances such as:



crude oil

paraffin – used to make candles, waxes and to produce cosmetics



vaseline – an ingredient in creams and ointments



mineral oils – from which engine oil and cosmetics are made



paraffin oil – an ingredient in the fuel for aeroplanes



iron

Iron ore is rock with iron in it. This is the form in which it is extracted from underground.



Iron is used to produce steel, which is used for:



cutlery



building structures



aircraft



Iron is also used to make kitchen utensils, among other things.



lead

Lead is heavy, which is why divers use it as ballast (see pages 8-7).



It is used to make a keel – the part of a ship that guarantees its stability.



Lead is used to stainer-glass windows, where the coloured glass is framed with lead.



Lead is used to make protective covers that block harmful radiation.



In the past, printing blocks were made of lead, mixed with some tin and antimony.



copper

Copper is used for:



Copper is a good conductor of electricity, which is why it is used in electronic appliances.



Under the influence of air and moisture, chemical compounds form on the surface of copper, that is why after a few months copper roofs start to take on their characteristic greenish colour.



Brass is an alloy of copper and zinc, and it is cast to make:



Brass is resistant to the erosion of seawater, and so steel is coated with it to prevent rusting.



An alloy is a combination of two or more metals forming a single new substance. Copper is the predominant metal in several important alloys.



Tools from the Bronze Age (around 3000–5000 years ago)



Brass is an alloy of copper and zinc, and it is cast to make:



utensils



coins



door handles



musical instruments



Gunmetal is a hard alloy of copper, tin, zinc and lead. In the past it was used to make cannon. It is still used to make bells and statues.



tin

zinc

zinc

zinc + lead

zinc

zinc ore



Zinc is resistant to the erosion of seawater, and so steel is coated with it to prevent rusting.



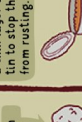
It is used to manufacture a pigment that gives paints a white colour



It is used to produce batteries

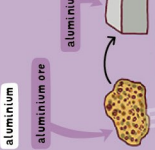





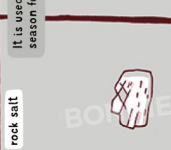
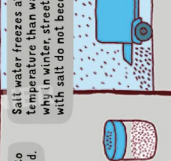

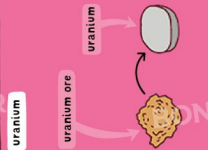

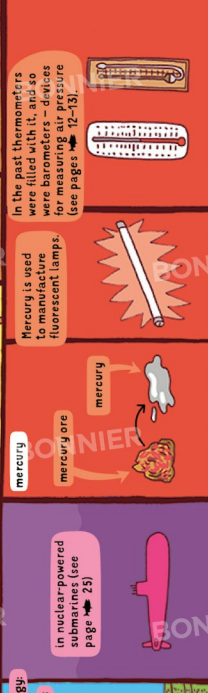
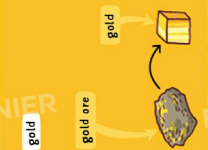


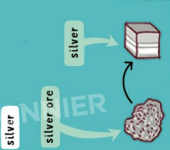










Steel cans for preserved food are made of a thin layer of tin to stop them from rusting.



In the past, tin along with lead and antimony was used to cast printing blocks.



<p>aluminium</p> <p>aluminium ore</p> 	<p>Aluminium is used for:</p> 	<p>Alloys of aluminium are light and durable, and so they are used to make important parts for cars, planes, trains, ships and bicycles.</p> 
<p>rock salt</p> 	<p>It is used to season food.</p> 	<p>Aluminium is a good conductor of electricity, and it is also light and cheap, so it is used to make cables that carry electricity great distances.</p> 
<p>uranium</p> <p>uranium ore</p> 	<p>It is used to produce energy at nuclear power stations</p> 	<p>Sulphur is an ingredient in many medicines (the oldest known explosive) and is one of the ingredients in match heads.</p> 
<p>gold</p> <p>gold ore</p> 	<p>Gold is used for:</p> 	<p>In the past thermometers were filled with it, and so were barometers – devices for measuring air pressure (see pages 12–13).</p> 
<p>silver</p> <p>silver ore</p> 	<p>It has antibacterial properties, and so it is used in dressings.</p> 	<p>Gold reflects the harmful radiation present in outer space, and so astronauts' suits are coated with it.</p> 
<p>precious stones</p> <p>diamond</p> <p>emerald</p> <p>sapphire</p> <p>ruby</p> 	<p>Some fabrics have silver fibre added. The clothes made of it protect the body against bacteria and fungi – silver effectively kills them.</p> 	<p>Compounds of silver coat the rolls of photographic film used in traditional photography.</p> 
<p>precious stones</p> <p>diamond</p> <p>sapphire</p> <p>emerald</p> <p>ruby</p> 	<p>Some fabrics have silver fibre added. The clothes made of it protect the body against bacteria and fungi – silver effectively kills them.</p> 	<p>Some precious stones also have other uses. They are hard (diamond is the hardest natural material), and do not decay or erode. They are used to produce specialised lasers, needles for playing vinyl records, ball bearings in watches and other very small parts that have to be precise and damage resistant – such as the parts for medical appliances.</p> 
<p>precious stones</p> <p>diamond</p> <p>sapphire</p> <p>emerald</p> <p>ruby</p> 	<p>They are used for jewellery</p> 	<p>Mercury is used to manufacture fluorescent lamps.</p> 

THE SUPER-DEEP BOREHOLE

In the far north of Russia, beyond the Arctic Circle, scientists drilled the world's deepest hole to gain better understanding of the Earth's structure. The borehole took 22 years to create and was more than 18km deep.

borehole 50-3



research centre on the Kola Peninsula



The borehole is located on the Kola Peninsula, a research rig, which is the highest building on-site. The drilling began in 1970 and finished in 1992. Nowadays the centre is abandoned and in ruins.

Nowadays has left succeeded in drilling through the Earth's crust - meaning the layer of rock that covers our planet. The world's deepest borehole did not even reach half way down - at this point, the Earth's crust is about 35km thick.

You will learn more about Earth's crust on pages 60-61.

borehole
Earth's crust



Drilling the super-deep borehole was a journey in time. As the drill broke through each successive layer of rock, it reached older and older seams. At the very bottom of the borehole, the scientists came upon rocks that formed up to 2 billion years before the first animals appeared on Earth.



The scientists collected numerous rock samples from various depths and built up an enormous collection that gives us better knowledge of the history and structure of the Earth.

Some of the rocks are billions of years old.



storeroom for rock samples



To replace the drill bit with a new one and extract the collected samples the entire drilling machine had to be brought out to the surface. During the life of the project the operators did this hundreds of times.

container for rock samples

The scientists wanted to drill down to a depth of 15 kilometres, but they had to stop the work before reaching their goal. They were surprised to find that at a depth of 12 kilometres it should be 100°C, but it turned out to be much hotter there - as high as 180°C. If they had reached the planned depth, they would have had to deal with a temperature of 300°C! The drill bit they were using would not have withstood such conditions.

Thanks to the super-deep borehole many remarkable scientific discoveries have been made. Some theories about the structure of the Earth proved to be wrong, knowledge about the inside of our planet is still incomplete, and there are many things we can only guess. The borehole showed that our guesses are not always correct, and that the Earth is still concealing many secrets.

-12,262m

MOVING JIGSAWS

The outer layer of the globe is called the lithosphere. It includes the Earth's crust and part of the mantle (see pages 60-61). It is made of rock, and at various points it is from 10-200km thick.

The lithosphere is divided into sections called tectonic plates. They resemble gigantic jigsaw puzzle pieces surrounding the entire Earth.

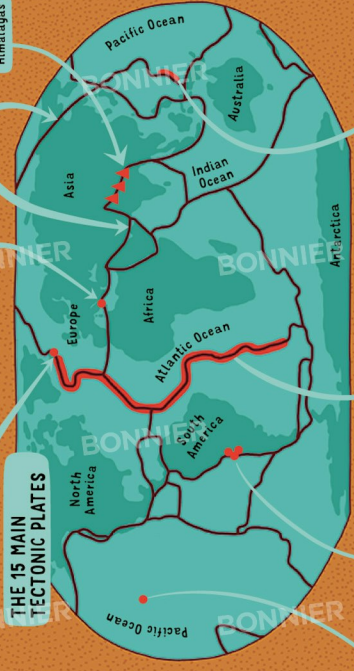
These pieces of the Earth's jigsaw are always moving, though very slowly. They collide with each other, clash and split, creating mountain ranges, ridges and trenches, and causing earthquakes and the development of volcanoes.

The largest number of volcanic eruptions and earthquakes occur in regions where tectonic plates meet.

THE PACIFIC RING OF FIRE



THE 15 MAIN TECTONIC PLATES



Hécla, one of Iceland's most active volcanoes.

Vesuvius in Italy is the only active volcano in continental Europe.

areas with the largest number of active volcanoes and earthquakes

Most earthquakes and volcanic eruptions occur in the zone known as the Pacific ring of fire, where most of the world's tectonic plates around the Pacific Ocean.

The world's highest volcanoes are: Ojos del Salado (6893m above sea level), Lullaihuac (6739m above sea level), and Tipas (6656m above sea level).

The Mid-Atlantic Ridge is a vast underwater mountain range. It is 16,000km long, and up to 600km wide. Each year it widens by another 2.5cm.

Mariana Trench (see pages 43-44)

20 million years ago as the result of the collision of two tectonic plates - the Indian and the Eurasian - the Himalayas were formed. The plates are still shifting, and so the Himalayas are still rising - each year they gain 5mm.

The world's highest volcanoes are located in South America. They are formed by colliding tectonic plates. How does it happen?

Not all volcanoes are on the edges of tectonic plates. Some are formed above hotspots, meaning places where hot magma gathers underneath the lithosphere. That is how Hawaii was formed.

When two plates below the ocean meet, one can slide under the other. The ocean trench is formed. The deepest one - the Mariana Trench - was formed in this way too.

When two neighbouring plates under the ocean are pushed together, the ocean trench is filled with hot magma from the Earth's interior that solidifies, forming a mid-ocean ridge. That is how the Mid-Atlantic Ridge was formed.

The main tectonic plates are divided into many smaller ones. They are constantly moving on deeper situated layers of rock, and their movements cause earthquakes.

Himalayas

When the plates collide, one of them slides under the other, and the magma that is pushed out melts to produce volcanoes, which come to the surface, creating volcanoes (see pages 56-57).

The Pacific plate shifted above a hot spot, creating a series of volcanoes from which the islands were formed.

volcanoes

islands

hotspot

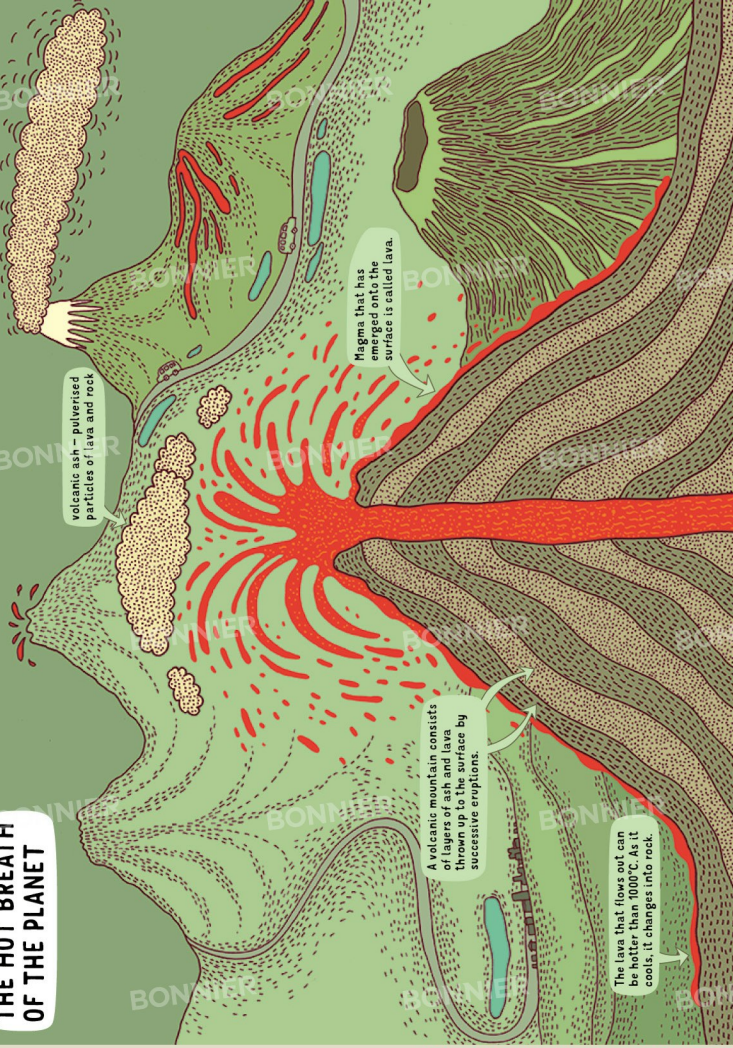
Hawaii

Mariana Trench

Mid-Atlantic Ridge

earthquakes

THE HOT BREATH OF THE PLANET



volcanic ash – pulverised particles of lava and rock

Magma that has emerged onto the surface is called lava.

A volcanic mountain consists of layers of ash and lava thrown up to the surface by successive eruptions.

The lava that flows out can be hotter than 1000°C. As it cools, it changes into rock.

During a violent volcanic eruption, a fountain of lava and crushed rocks can shoot up hundreds of metres, and a cloud of ash can rise to several kilometres into the sky. This sort of eruption can destroy an entire city. But volcanoes do not only bring destruction – if not for volcanoes, our planet might have looked completely different.

Billions of years ago, when the Earth was only just forming, it was full of active volcanoes. From the interior of the planet they brought to its surface heat, water, and vast amounts of carbon dioxide and other gases, which gave rise to the Earth's atmosphere.

We are still not entirely sure how life on Earth began. One of the theories states that it may have been gas emerging from volcanoes that caused the development of the first living organisms. The basic compounds that comprise proteins – the basic building material for all living organisms.

As life was first forming on Earth, it must have been hot. Volcanic ash is rich in phosphorus, potassium and magnesium, making the land around many volcanoes some of the most fertile on the planet.

Volcanoes are also responsible for the formation of new land masses. Hawaii, Iceland and the Galapagos Islands were all made of solidified lava expelled by undersea volcanoes.

Under the pressure of the surrounding rocks, magma is pushed upwards. The place where it comes out onto the surface is called a volcano.

Magma is a fluid mass consisting of melted rocks and is pushed upwards by the pressure of the upper mantle. It can be as hot – its temperature can be as high as 1300°C. It develops deep underground, in the Earth's crust or the upper mantle (see pages 56–60–61).

Volcanoes divide into active, dormant and extinct. But not everybody understands these concepts in the same way.

According to one of the definitions, a volcano is active if it has erupted at least once in historical times. It has been roughly during the past 5000 years. But some scientists extend this period to 10,000 years. Depending on the definition used, there are from 500 to 1500 active volcanoes in the world.

A dormant volcano is one that has shown no sign of activity for many thousands of years, but might wake up and erupt again in the future.

A volcano is regarded as extinct when it has no more layers of magma underneath it, and so is most unlikely to erupt ever again.

Volcanoes are often regarded as extinct or dormant on the basis of criteria that have been used since their last eruption. This is not a good method, because sometimes millions of years go by between eruptions, and volcanoes thought to be extinct have been known to erupt again.

Scientists believe that magma can form up to 250 km below the Earth's surface.

HOW THE EARTH BOILS WATER

The Earth's interior is like an enormous oven, in which even rocks are melted. There are places in the world where water is boiled by the Earth. This can create geysers, hot springs, that send up a pillar of water and steam.

They are only found in regions of the world where there are volcanoes. The largest number are in Yellowstone National Park in the United States, but there are many in Iceland, New Zealand, and Chile.

The geyser that sends up the highest pillar of water in the world – to a height of 90m – is Steamboat, located in Yellowstone Park. Its eruptions are not regular, but sometimes as much as 50 years.

From the moment it first flows underground to the moment when it gushes out of the geyser, the water makes a long journey. This can take as long as 500 years!

How do geysers work?

- 1** Water that comes from rain, snow, and sometimes from nearby rivers seeps through cracks and fissures in the rocks, flows deep underground and gradually fills the geyser's channel.
- 2** Magma constantly heats the rocks and the water located in between them.
- 3** As it boils, the water abruptly turns into steam, causing its volume to increase greatly. As a result, a pillar of steam and water shoots out of the narrow channel.
- 4** The eruption of a geyser can last for many minutes, until the moment when there is no more water inside it, or when it cools down and stops boiling. Then the channel starts to fill up again, and the process is repeated.
- 5** The temperatures of the water keep rising until it starts to boil. The little bubbles of steam that appear in it rise upwards and push some of the water out of the channel to the surface. This reduces the pressure in the lower parts of the channel and the water starts boiling.
- 6** As the pillar of water in the geyser's channel rises higher and higher, it presses harder on the hot water in the lower part of the channel. The result is that the water in the lower part of the channel starts to boil. This means that the water does not start to boil, even though, with time, the temperature rises far above 100°C.

When you heat water in a kettle, it starts to boil, changes into steam when it reaches a temperature of 100°C. But under high pressure water behaves differently – it needs far more heat to boil. When the water is close to boiling, it is strong enough to hold its pressure for a while, and that is what happens in geysers.

In places where geysers are formed there is hot volcanic magma only a few kilometres underground.

DEEP UNDERFOOT

It is not easy to research the Earth's interior. We are more than 6300km from its centre, and the deeper down, the tougher the conditions. Thanks to extremely hot temperatures and high pressure we are incapable of reaching or seeing really deep down. So how do we know what is in there?

To research the Earth's interior scientists use seismic waves, meaning the 'vibrations' that run in all directions during earthquakes. When an earthquake is very powerful, these waves can pass right through the planet's interior.

The speed at which seismic waves travel changes depending on temperature, pressure, and what sort of material they pass through. By researching these waves scientists have drawn conclusions about how the Earth is constructed, but many things are still unknown.

Earth's crust

The Earth's crust, meaning the outer, rocky layer, is from 5-70km thick. It is thinner beneath the oceans, and thicker beneath the continents.

approx. 410km approx. 600km

Transition zone

The mantle is a thick layer of rocks where the temperatures are different at various depths, depending on the pressure and temperature prevailing there.

lower mantle

ok. 2300km

core (see pages 62-63)

approx. 6370km

discontinuity

Discontinuities are transition zones – the borders between layers of the Earth's sphere. As they pass through a discontinuity, the seismic waves change their speed suddenly. The discontinuities are named after the scientists who discovered them.

Gutenberg discontinuity

The temperature of the rocks in the mantle is from 500°C to 4000°C, depending how close they are to the Earth's core. Most of them are not molten, but in deeper parts of the upper mantle they are hot enough for the atoms to be able to move over them (see pages 59-55).

Although the Earth's crust only seems to be a thin layer surrounding our planet, so far it has been a barrier that mankind cannot penetrate. No one has ever seen what lies deeper down – we know about it mainly thanks to researching seismic waves.

At the bottom of the Atlantic Ocean there is a vast area where the Earth's crust is missing. Here at a depth of 3km lies an exposed part of the mantle.

Researching the Earth's interior: scientists

The kinds of seismic waves which can spread anywhere, and transverse waves, which do not pass through liquids. Thanks to this they have discovered that the Earth's core is partly liquid – transverse waves do not pass through it.

A seismograph is a device used to record the Earth's tremors – in other words seismic waves.

Site of an earthquake

Transverse waves

longitudinal waves

Earth

THE CENTRE

Where on Earth is the point that is furthest away from its centre? Despite appearances, it is not the highest peak, Mount Everest, but the far lower summit of a volcano called Chimborazo, in Ecuador.

Chimborazo volcano, 6258m feet above sea level.



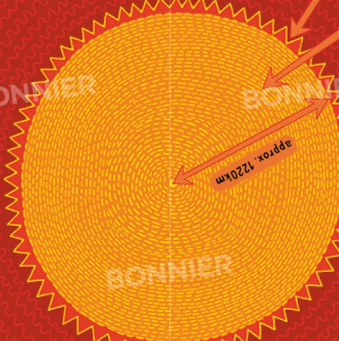
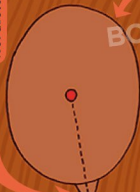
Most 250km below the surface the Earth's core begins. The core is the deepest part of our planet, it consists of two parts: the outer and inner core, and it consists of metal, nickel and iron.

Thanks to the development of research on seismic waves and improvements to equipment, our knowledge of the Earth's structure and of its core are becoming more precise.

shape of the Earth

For many years it was thought that the entire core of the Earth was fluid. In 1936 Danish scientist Inge Lehmann discovered that its central part is a large metal sphere, can distinguish two slightly different parts.

The Earth is not a perfect sphere - it is flattened at the Poles, so the distance between its surface and its centre is greatest on the Equator. And the Ecuadorian volcano is the highest peak located in the vicinity of the Equator.



approx 1220km

approx 6370km

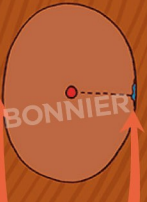
The outer core is fluid.

The inner core is a metal sphere with a temperature of about 6000°C - close to the temperature of the Sun's surface.

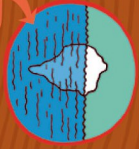
transition zone known as the Lehmann discontinuity

The Gutenberg discontinuity separates the molten core from the solid mantle.

The Earth's sphere, flattened at the Poles



Arctic Ocean



Because the Earth's sphere is slightly flattened, it is at the Poles that the distance between the surface of the Earth and its centre is the shortest.

The place of the planet that is closest to the centre of the Earth is underwater - not far from the North Pole, at the bottom of the Arctic Ocean, at a depth of 5650m.

The ocean bed is one of the least known and most inaccessible places on Earth, and the deeper it lies, the harder it is to explore. So far, only three people have ever managed to descend to its very deepest point – the Challenger Deep at the bottom of the Mariana Trench.

One of them is the Canadian film director and oceanographer James Cameron. In March 2012 he spent three hours at a depth of almost 11km in the world's deepest and most remote vessel called the *Deepsea Challenger*.

During the expedition he collected some valuable finds – rock and silt samples, from previously unathoanable depths, and live organisms capable of surviving in the difficult conditions prevailing there.

antenna

When the vessel resurfaces at night, flashing lights help it to be found on the surface of the ocean.

Deepsea Challenger

DEESEA CHALLENGER EXPEDITION
Date: 26 March 2012
Depth reached: 10,900 metres
Time submerged: 2 hour 36 minutes
Time spent on the sea bed: 3 hours
Time resurfacing: 70 minutes

You can

read the facts about why some things float and others sink on pages 6-7 and about the pressure prevailing underwater on pages 12-13

lights

The hull is made of foam lighter than water and resistant to the immense pressure at the bottom of the ocean. As a result, after dropping its ballast, the vessel comes up to the surface.

batteries

engines that allow the vessel to move up, down, and forwards

3D Camera

In the water, the vessel falls to the bottom thanks to its ballast (its load of steel plates, each of which weighs 100kg). To rise, the vessel has to drop the ballast. Then the vessel starts to re-emerge.

ballast

Dropping the ballast is an important operation. If it were to fail, the pilot would be stuck at 8,000m. In such a case, there are various ways for him to activate it. If none of them were to work, within 13 hours the cables holding the ballast would be destroyed by seawater, releasing the steel plates, and the vessel would resurface.

The cabin walls are more than 6cm thick.

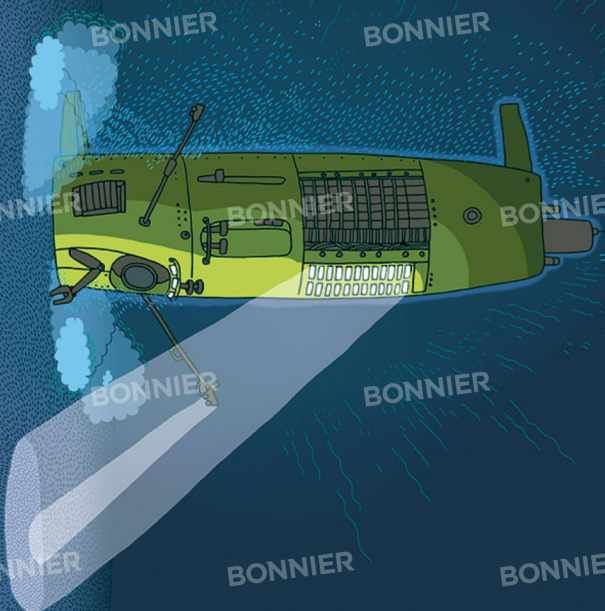
foodlight

Inside the vessel, the pilot cannot stand up on stretch his legs. The vessel is so tight that he has an inner diameter of only 109cm, and there also has to be room for electronic equipment. The pilot uses these machines to steer the vessel, collect material for research, film and light up the sea bed, and to communicate with the crew on the surface.

pilot's cabin

smart-remote-controlled arm that the crew use to collect rock samples and tiny sea creatures

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THE MARIANA TRENCH

The deepest known point on Earth is situated in the Pacific Ocean, in a huge trench more than 2500m long. It is close to the Mariana Islands, and so is called the Mariana Trench.



The depth of the trench was first measured in 1875 by the crew of the ship *HMS Challenger*. It was the deepest of the measurements taken within the world, researching the oceans and the life present in them.

Since then many attempts have been made to measure the depth of the Mariana Trench at the deepest point. The measurement taken by the crew of *HMS Challenger* showed a depth of 8105m, but according to the most recent data, the deepest point of the trench, the Challenger Deep, is 10,984m from the surface.

The crew of the bathyscaphe *Triton* did not take any photographs during their descent, but they saw underwater from their accounts. The remote-controlled robots that fathomed the Mariana Trench many years later were equipped with cameras and other devices. They were able to see rocks, basaltic and marine organisms from the bottom of the ocean.

A bathyscaphe is a deep-sea vessel in which a spherical cabin is attached to a large hull that provides displacement.

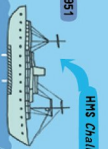


1 In the 19th century, when no other means were yet available, depths were measured by attaching weights to one end. They were lowered until the weight hit the bottom. Then the length of the section of rope underwater was measured.



2 In the mid 20th century there were already far more precise ways of measuring depth. The crew of the ship *HMS Challenger* / *Albatross* used the Mariana Trench using a sonic depth finder, and gained a result of 10,930m.

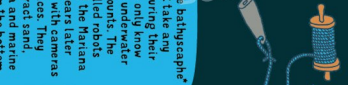
A sonic depth finder emits sound waves that bounce off the seabed, avoiding obstacles and return to the ship. The depth of the water is determined on the basis of the time it takes for the emitted waves to return.



3 American Don Walsh and Swiss Jacques Piccard were the first people to reach a depth of 10,911m in 1960. They spent almost 5 hours in the small cabin of the bathyscaphe "Triton". They found themselves at the bottom of the Mariana Trench.

They spent 20 minutes observing the ocean bed through a tiny window. They claimed to have seen a fish, but nobody knows if it was real. It is hard for many scientists as fish could survive at such a depth.

This is what the ship would look like if drawn on the same scale as the Mariana Trench in this illustration.



Lead line, meaning a rope with a lead weight for measuring the depth of water

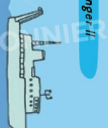


Lead weight

5 Remotely-operated American robot *Arcturion* showed a depth of 10,922m

During the expedition, the robot was connected to the ship by a cord made of glass fibre the thickness of a human hair. Via this cord the robot communicated with its operator.

Length: 3m



1960 bathyscaphe "Trieste"

length: 10m



1995 Remotely-controlled Japanese robot *Kairei* reached a depth of 10,911m.

length: 3m



1972 Deepsea *Challenger* expedition

(see pages 44-45)

-10,984 m

-10,000m

-9,000m

-8,000m

-7,000m

-6,000m

-5,000m

-4,000m

-3,000m

-2,000m

-1,000m

ANGLERFISH AND LANTERNFISH

Many deep-sea fish hunt with the help of bioluminescent lures that resemble fishing rods. With a lure attached to the end, when the victim is lured by its movement and swims close enough, the fish opens its jaws and swallows its prey.

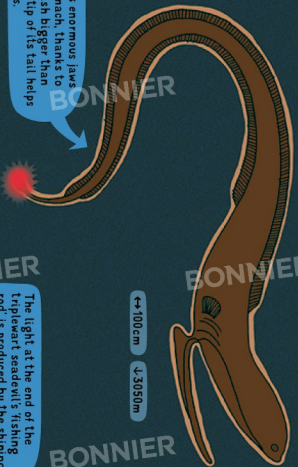
These lures come in various strange shapes, such as this one, resembling spiny twigs.



barbed dragonfish

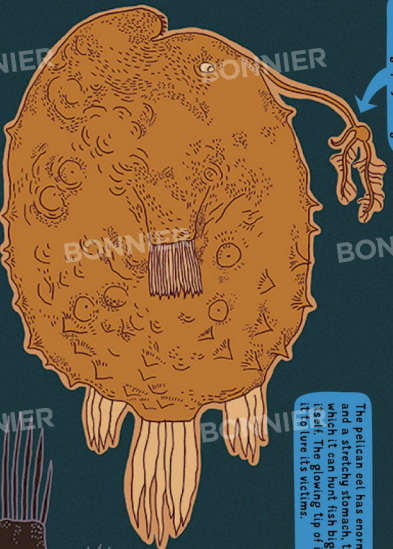
↔ 155cm ↳ 533m

The pelican eel has enormous jaws and a stretching stomach, thanks to which it can hunt fish bigger than itself. The glowing tip of its tail helps it lure its victims.



↔ 100cm ↳ 3050m

The light at the end of the pelican eel's stomach is fishing for bioluminescent bacteria that live in there.

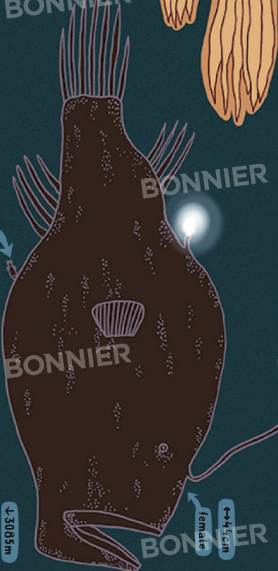


giant barrelfish

↔ 40cm ↳ 1360m

↳ greatest observed length

↳ greatest observed depth at which found



male ↔ 7cm

female

↔ 45cm

↳ 3035m

humpback anglerfish

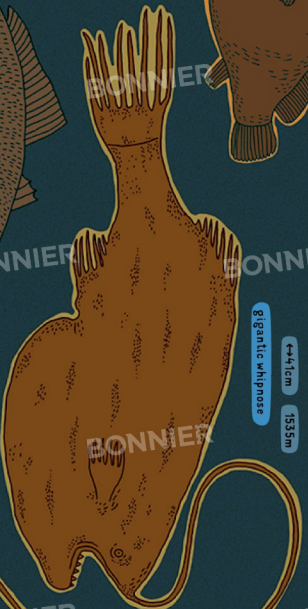


female

↔ 40cm ↳ 1360m

giant whipnose

↔ 47cm ↳ 535m



Some fish that live in total darkness produce their own light. To do this for them, they have glowing organs called photophores.

The light attracts the marine creatures on which these fish feed. It also comes in useful for mating. When the male and female find each other in the dark,

spotted lanternfish

↔ 11cm ↳ 1000m



↔ 35cm ↳ 400m



wolftrap angler

↔ 25cm

↳ 400m



Pacific viperfish

↔ 28cm ↳ 380m

↳ 11

The splitfin flashlightfish has a glowing organ under its eye which it operates as a torch. It can switch it on and off. When the fish is in or out, it uses it to look for food in the dark, to mislead predators, and also to communicate with other fish of its own species. The light is produced by bacteria that live under the fish's eye.

DEEP DWELLERS

The deeper we go underwater, the fewer living organisms we encounter. Yet, there are creatures that live several thousand metres below the surface. We know next to nothing about many of them, and some species are only known from a single specimen. The ocean depths are probably full of unknown species of fish, octopus, squid and other unusual animals.

Deep down the water is icy and sometimes it contains very little oxygen. Squid and other animals that live there, so total darkness reigns. The animals that have adapted to these tough conditions are different from the ones that live close to the surface – they often look like strange, mismatched versions of them.

↑7cm ↓600m



sparkling enope squid

↑↑30cm ↓3000m



burr-eye

↑↑10.5cm ↓900m

black snaillover before feeding



↑25cm ↓2745m



common fangtooth

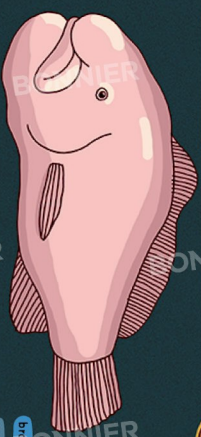
↑↑18cm ↓5000m



brownout snookfish

↑↑18cm ↓2400m

The black snaillover devours whole fish that are up to 10cm long. It has a very long, thin stomach. The victim ends up in the snaillover's stretchy stomach where it is digested.

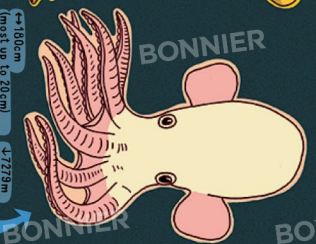


↑30cm ↓2000m the jelly-like blobfish



slender snipe eel

↑↑120cm ↓↑337m



↑↑18cm (most up to 20cm) ↓2773m

First that resemble elephant ears are a typical feature ofumbo octopuses that live deep down. They include record breakers from the genus *Grimpoteuthis* that are found on the ocean bed at depths exceeding 7000m



↑↑30cm ↓8143 m

The deepest observed fish is a specimen of an unknown genus from the family known as *Uperidae* (snailfish). Scientists came across it in the Mariana Trench at a depth of 8149m. It was filmed by the camera attached to a device for collecting samples that was lowered to the ocean bed.



↑↑75cm ↓3500m

vated anglemouth



↑↑76cm ↓2140m (most up to 36cm)

Like many deep-sea fish, the spiny-headed batfish spends its days in darkness deep under water, and at night it swims towards the surface in search of food.

↑↑45cm ↓2400m

UNDERWATER CHIMNEYS

At the bottom of the ocean hydrothermal vents, also known as 'black smoker' vents, or metes underwater unusual places like hidden that resemble foci of smoking chimneys. The clouds that emerge there are not smoke, but hot water full of minerals.

Known as hydrothermal vents, these chimneys are formed in places where the Earth's volcanic activity is high – for example where tectonic plates collide (see page 44, 54–55). In order for them to develop, there needs to be a source of heat. The seabed, heated from below by volcanic magma, when the seawater reaches them, it is heated to great temperatures (as much as 400°C), and under pressure emerges through pressure vents. The water mass is contained in the water settle around these cracks, creating chimneys that grow at a speed of up to 2m per year.

The rare life forms that exist at these depths gather around the hydrothermal vents. Bacteria develop there that feed on hydrogen sulphide emerging from the chimneys. They attract larger organisms for which they are a food.

Giant tube-worms can grow to 2.5m in length. These unusual animals live in symbiosis with the bacteria. This means that they cooperate with them, exchanging substances essential for life.

The deepest located hydrothermal vents are found at a depth of 5000m below the surface.

-5000m

The Lost City is inhabited by snails, mussels, crabs, sea urchins, corals and bacteria. Over half of the species found here do not feature anywhere else on Earth. Scientists believe that it was at this sort of site of volcanic activity that the first forms of life on Earth may have developed.

The Lost City

In the year 2000, during an expedition to research the Atlantic tectonic plates, scientists situated at the bottom of the Atlantic Ocean discovered a unique place which they named The Lost City. It is a field of volcanic chimneys, previously familiar to black smoker vents.

The water that emerges here from under the seabed does not exceed a temperature of 90°C and is full of limestone. In contact with cold seawater it produces white deposits that over time form tall, thin, tower-like structures. The highest one, named Poseidon, is 60m tall.

-8000m

THE TITANIC

On 10 April 1912 the huge liner *Titanic* was unsinkable, set off on its maiden voyage. A few days later it hit an iceberg and sank, taking more than 1500 passengers to the bottom.

The search for the wreck of the *Titanic* took over 70 years. Not until 1985 did an expedition led by American scientist Robert Ballard come upon the remains of the wreck, scattered across an area of several kilometres surrounding the ship's hull.



route of the *Titanic*

site where the ship sank

New York

Atlantic Ocean

Southampton

To search the wreck, a special rig called *Argo* was used. It was lowered underwater to allow the cameras attached to it to film the ocean bed. The images were sent to the surface to the research vessel towing *Argo*.

At first the researchers explored the wreck of the *Titanic* with the help of sonar equipment (see page 25). The results, only by using cameras to comb the sea bed did they achieve success.

The wreck of the *Titanic* lies at a depth of 3800m, for years scientists believed that it must have remained in an unspoiled state because of the conditions prevailing deep down. They thought that in view of the low temperature and high pressure there would not be enough living organisms at that depth to cause it to decompose.

The truth proved very different. The wreck is gradually decaying, and is full of living creatures: fish, crabs, shrimp and mussels that are gradually eating away at the rusting steel. According to some scientists in the next fifteen years or so it will entirely decompose.

Ever since the wreck was found many expeditions have been organised to the site where the *Titanic* rests. A year after its discovery Robert Ballard returned there on board *Alvin*, a three-person research vessel.

Alvin was equipped with a small, remote-controlled robot that could swim inside the wreck and reach places inaccessible to the vessel.

According to United Nations estimates, there may be more than 3 million sunken ships at the bottom of the world's seas and oceans. Some of them serve as tourist attractions for scuba divers. Some are very old – scientists study them to learn about the life and customs of people who lived hundreds of years ago. Many have never been found.

-3800m

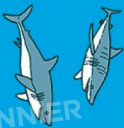
SCIENTISTS UNDERWATER

Scientists study the depths in small, 3- or 6-man research vessels (known as submersibles), equipped with cameras and mechanical arms controlled from the cabin.

As distinct from naval vessels, research craft usually have windows. In vessels adapted for very great depths these are small because of the immense pressure deep down, but in the ones that do not descend to such depths the windows are metres, large windows allow the crew to admire the view freely.



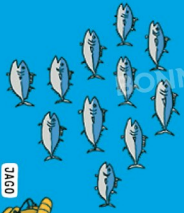
SR3000/3



Trogl

French film maker Fabien Cousteau had the idea of constructing a submersible that looked deceptively like a great white shark. This made it possible for him to swim among the sharks, filming and observing them.

Prior then nobody knew how sharks behave without people in the vicinity. Fabien Cousteau tried to find this out by pretending to be one of them.



JACO

SP-350 Demise



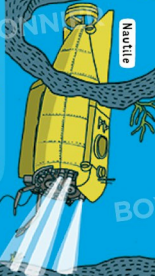
This two-man vessel, built in 1959 by the French marine scientist and explorer Jacques Cousteau, could descend to a depth of 300m.



Deepworker



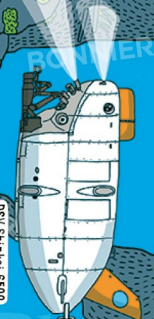
Johnson Sea Link II



Nautilus

The crew of the *Nautilus* can send Robin – a remote-controlled robot – into almost inaccessible places.

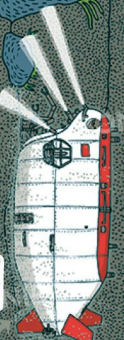
There are only a few research vessels in the world that can reach a depth of more than 3000m.



OSV Shinkai 6500

This three-man Japanese submersible can descend to 6500m.

Submersibles *Mir-1* and *Mir-2* have taken part in underwater expeditions to the North Pole, and to the deepest lake, Lake Baikal. They have also been used to film the wrecks of sunken ships, including the *Titanic*.



Xiaolong

Chinese submersible *Xiaolong* is one of three manned vessels that have gone down to depths of more than 7000m. The two others are the bathyscaphe, *Trieste*, and *Deepsea Challenger* (see pages 42–45).

After a serious accident, a German scientist and cave diver Jochen Hasenpferger lost the use of his legs. To carry on working he designed a special craft in which he floated covered.

Spektronaut



In many parts of the world there are enormous structures made of steel and concrete rising out of the seas and oceans. These are platforms (or rigs) set up above deposits of crude oil and natural gas to extract these natural resources from under the seabed. There are many different types of platform.

Concrete structures stand stably on the sea bed thanks to their immense weight. The biggest structure of this kind is the Norwegian Platform, Holt A, which is 174m high.



Concrete structure



This platform floats on the surface of the sea like a buoy. It is attached to the sea bed by cables or taut cables.



A float filled with air raises the platform to the surface.



This platform stands on a large steel frame filled with air, which is weighted to maintain it on the surface.



A specially weighted chamber keeps the shaft of the platform upright.



The foundation is buried deep in the seabed.



Platforms that stand on towers attached to the seabed are built in places where the water depth does not exceed 500m.

The platform is fastened to the seabed with the help of ropes.

Chains anchored to hold the platform in place in the strong sea currents.

The biggest oil platforms are among the tallest structures built by humans. They are as tall as some of the tallest skyscrapers that of many skyscrapers.

Several hundred people can work on a single platform, which becomes their temporary home. The workers sleep and relax at sea, and only go back to land every few weeks.

natural gas

The deepest anchored rig in the world is the Perdido oil platform in the Gulf of Mexico, which rises on a floating cylinder. It is fixed to the seabed at a depth of 2,829m.

Deposits of oil can be found as deep as several metres under the seabed.

crude oil

The colossal squid is a gigantic sea creature, regarded as the biggest invertebrate animal with no backbone on Earth. In terms of length it only takes second place to the blue whale. The largest of the colossal squid is the heavier (the largest found weighed 495kg) and more massive species.

It lives at depths of over 1000m in the waters of the Southern Ocean and Antarctic.

This enormous creature has the biggest eyes of all known animals – they can be as large as footballs. The squid uses them to detect prey and the predators that might attack it, for example sperm whales.

The squid's eyes are equipped with a small fovea. These allow it to see better in the all-surrounding darkness deep underwater.

Suckers and hooks are used to catch and hold on to food. The hooks on the longest tentacles can revolve 360°.

suckers

Only a few specimens of the colossal squid have ever been caught, and all our knowledge of them is based on these rare examples. The first discovery was in 1925, when two huge tentacles that did not belong to any known species were found in the stomach of a sperm whale. Since then whole specimens have been found, but all of them were dead or incomplete.

Nobody has ever seen a live colossal squid in its natural environment. They are not easy to keep in captivity, and we do not know that they are not uncommon. The stomachs of sperm whales are full of hard beaks, which remain inside them, left over from the numerous squid they have digested.

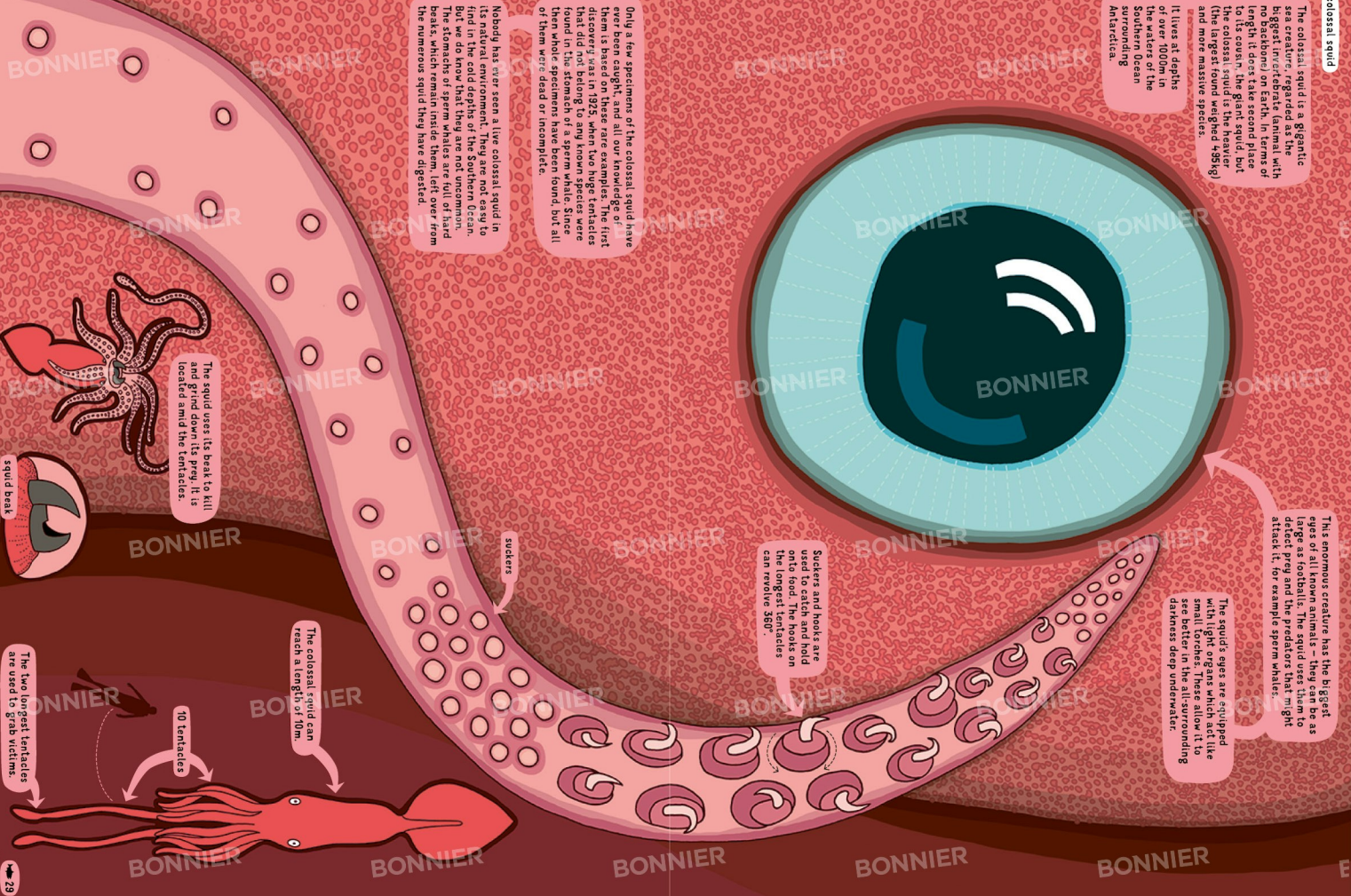
The squid uses its beak to kill and grind down its prey. It is located amid the tentacles.

squid beak

The colossal squid can reach a length of 10m.

10 tentacles

The two longest tentacles are used to grab victims.



GIANTS OF THE DEEP

blue whale

The blue whales is the biggest creature that has ever lived on Earth. Although some dinosaurs were longer, none of them equaled the blue whale in terms of bulk and weight.

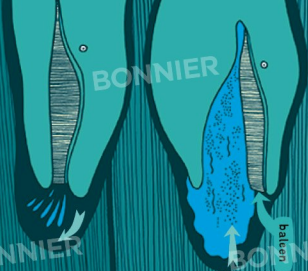
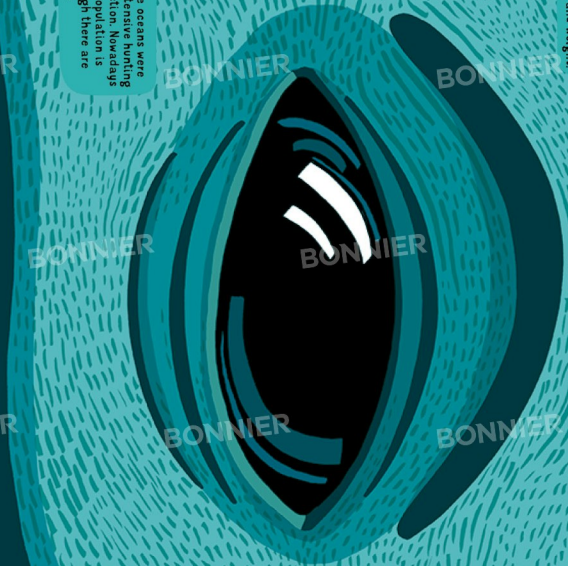
Until the early 20th century the oceans were full of blue whales. Later on, intensive hunting led to their almost total extinction. Nowadays the population is gradually growing again, though there are still far fewer than in the past.

Blue whales feed mainly on krill, which are tiny crustaceans. One individual can swallow as much as 4 tons of it daily.

Instead of teeth blue whales have baleen – very thin, densely aligned plates. They use them to strain the food that they take into their mouths along with the seawater. When they close their jaws and push the water out through the baleen, the tiny crustaceans and other organisms settle on it.

Despite their immense size, blue whales have a very narrow oesophagus – it has a diameter of only 10 cm. So they are not capable of swallowing bigger fish.

The blue whale is also one of the loudest animals on Earth. It emits protracted noises that are louder than a jet plane taking off. These sounds carry in the water for hundreds of kilometers, but their frequency is so low that the only way to hear them is by putting yourself within 10 km of the human ear.



The biggest blue whales exceed 30m in length and can weigh as much as 190 tons.

Blue whales rarely dive deeper than 200m below the surface of the water, but they do sometimes go down to a depth of 500m.

Stefan Drzewiecki's three-man craft

1902



periscope
hatch
storage area for mines

length: 6m

Holland II



1891
length: 6m

Stefan Drzewiecki designed several underwater craft. One of them was the first submarine to use a periscope. Another one was the first to be propelled using electrical power.

one of several vessels designed by Irish constructor John Philip Holland

John Philip Holland was the first to build a submarine that was driven on the surface by a steam engine, and underwater by electrical energy produced by batteries. This solution is still used today.

American engineer Simon Lake

applied many original solutions in his underwater craft. One of them was to use wheels on which the craft could drive along the sea bed.

Argonaut Junior



length: 4.2m

1934

Simon Lake's next craft was equipped through which airtight underwater. The air pressure in the chamber meant that when a hatch in the floor was open, the water did not pour inside.

Argonaut I



1897
length: 11m

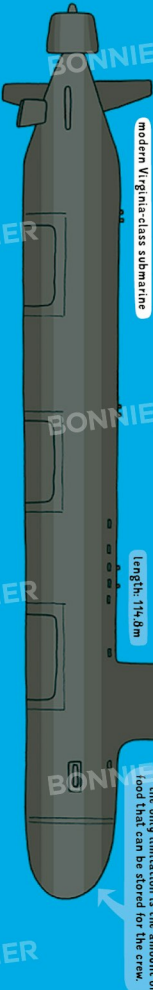
The first submarines only submerged for a short time, because their constructors were unable to store large supplies of air on board. In today's nuclear-powered submarines the air is constantly being made suitable for breathing, so they can stay underwater almost indefinitely.

The first submarines only submerged for a short time, because their constructors were unable to store large supplies of air on board. In today's nuclear-powered submarines the air is constantly being made suitable for breathing, so they can stay underwater almost indefinitely. The only limitation is the amount of food that can be stored for the crew.

underwater exit for divers

length: 114.6m

modern Virginia-class submarine



SILENT TRAVELLER

The modern submarine

The first underwater vessels were driven by human power – with the aid of oars, pedals or cranks. The one in this illustration has diesel-electric engines. There are also nuclear-powered submarines.

The advantage of diesel-electric submarines is that they can move very quietly underwater, which is very disadvantageous is that they have to come up to the surface once in a while to recharge their batteries.

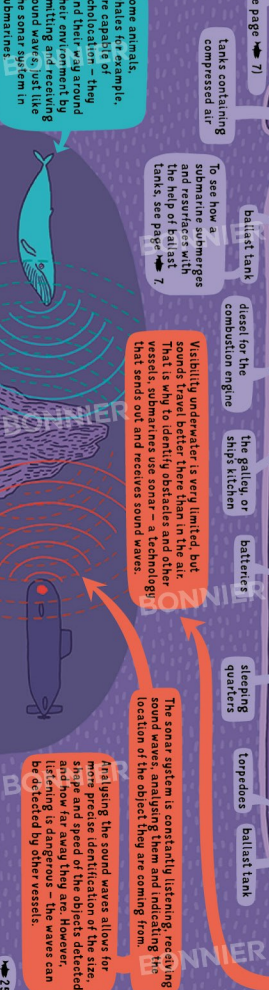
Nuclear-powered submarines are very expensive, and they make more noise when they are on the move. So they do stay underwater almost indefinitely.

Tanks full of compressed air are used while ascending. The pressurized air is released into the ballast tanks, pushing the water out of them.

The diesel-fuelled combustion engine is only used on the surface. It recharges the batteries that have been used up underwater.

Special devices, lantern non-stop to pouring the air perched by the crew and to replenish their supply of oxygen. areas from which the crew controls the craft.

Some animals, whales for example, are capable of finding their way around their environment by emitting and receiving sound waves, just like the sonar system in submarines.



To see how a submarine submerges and resurfaces with the help of ballast tanks, see page 7.

Visibility underwater is very limited, but sounds travel better there than in the air. That is why to identify obstacles and other vessels, submarines use sonar – a technology that sends out and receives sound waves.

The sonar system is constantly listening, recording sound waves, analysing them and indicating the location of the object they are coming from.

Analysing the sound waves allows for precise prediction of the location of the object, and how far away they are. However, listening is dangerous – the waves can be detected by other vessels.

THE FIRST SUBMARINES

In the 17th century the world's first submarine sailed on the River Thames in England. It was ear powered and built by Dutch inventor Cornelius Drebbel.



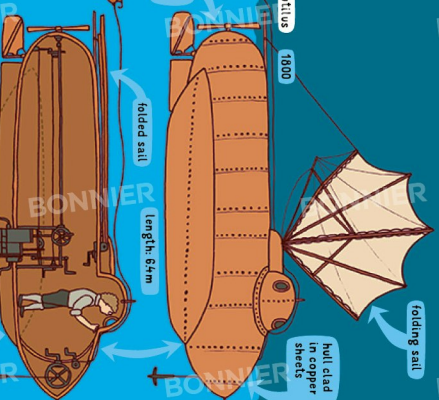
Cornelius Drebbel's vessel

wooden frame covered with leather

Drebbel built several vessels. The biggest one had room for 16 passengers and could stay underwater for several days. The designs for these underwater machines have survived, and so some of the solutions applied by Drebbel remain a mystery.

naval mine attached to the underside of an enemy ship

Nautilus 1800



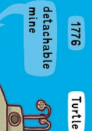
propeller driving the submarine

folded sail

length: 63m

folding sail

hull clad in copper sheets



1776 Turtle



length: 2.3 m

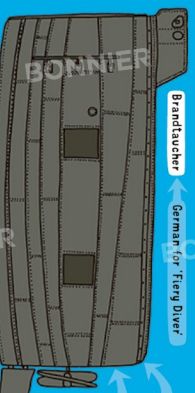
The man driving the vessel had enough air for 30 minutes.

propellers driving the craft

ballast tank full of water

American David Bushnell built a one-man submarine driven by human power. To submerge it, the man driving it let water into the ballast tank. To return to the surface he had to pump it out again.

Brandtaucher German for 'Tong Diver'



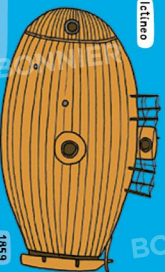
length: 8m

1850

This German vessel, built by Wilhelm Bauer, could descend to a depth of 95m.

The Brandtaucher sank in February 1851. Three members of the crew, including Bauer, were rescued. Twenty-six years later the vessel was brought up from the seabed. Today it is on view at a museum in Dresden.

Spanish inventor Narcís Monturiol i Estarriol built a submarine out of olive wood for coral fishers. It reached a depth of 20 meters, and its shape was inspired by the outline of a fish.



lifecycle

1859

length: 7m



Two crew members operated the propeller in motion. They drove the craft.

Like many other Brandtaucher took on water in order to dive, and rose to the surface when it was pumped out again.

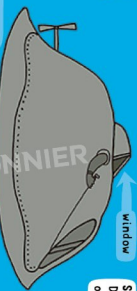


extra ballast

rudder for changing direction

propeller driving the vessel

Polish inventor Stefan Drewniecki constructed a one-man craft propelled in a similar way to a biplane – using pedals.



window

Stefan Drewniecki's one-man vessel

1877

length: 5m

The vessel was steered by sticking your arms out in special waterproof sleeves.

rudder for changing direction

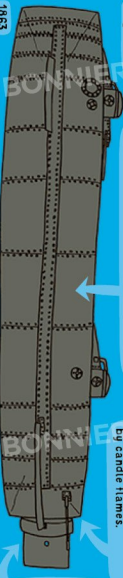


length: 12m

H.L. Hunley

This American vessel took part in the American Civil War. It was the first submarine in history to sink an enemy ship.

It was propelled by human power. Its interior was lit by candle flames.



In 1864, on the way back from a mission on a ship, the H.L. Hunley sank, dragging all eight crew members to the bottom. The wreck was brought up 156 years later.



ballast tank being filled with water

From the start, submarines were designed for military purposes when they built his first submarine, which he built his for the British navy. Both the Turtle and the Nautilus were constructed in order to sail underneath enemy ships and attach explosive charges to their hulls.

Inspired by medieval knights' armour, Alphonse and Theodore Carmagnolle constructed an impractical and unusual looking under-water diving suit. To protect the diver from the high pressure of the water, they covered it in steel plates, which were pressed to be watertight.

1878

The suit's inventors were not able to make a large glass surface that would withstand the high pressure underwater. To reduce the risk of the glass cracking, they used lots of small windows.

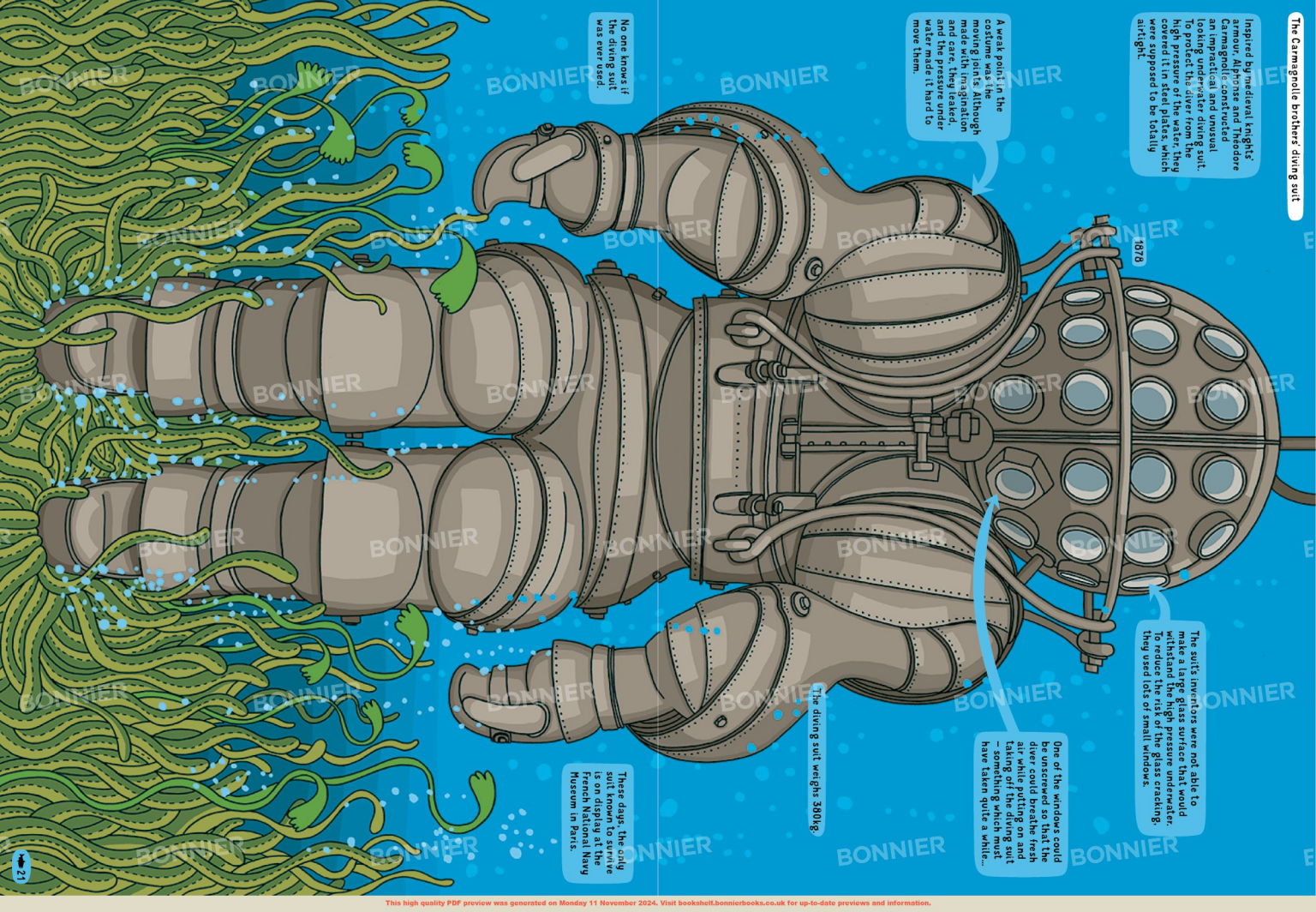
One of the windows could be unscrewed so that the diver could breathe fresh air while putting on and taking off the diving suit – something which must have taken quite a while...

A weak point in the costume was the moving joints. Although made with imagination and care, they leaked, and the pressure under water made it hard to move them.

The diving suit weighs 380kg.

No one knows if the diving suit was ever used.

These days, the only suit known to survive is on display at the French National Navy Museum in Paris.



OUR ANCESTORS UNDERWATER

The first primitive diving costumes were produced about 300 years ago. Ever since, inventors have been trying to create better and better deep sea diving suits. In the process they have discovered a large number of problems.

As they wanted the costume to protect the diver from the high pressure underwater, it had to be made of a durable material. But as a result it was often too stiff and heavy to move about in freely. Another major challenge was how to provide the diver with a supply of air to breathe.

A deep sea diving suit called 'iron Mike' was used in several searches for sunken ships. Thomas Connelley's invention was equipped with an air cylinder that allowed the diver to work underwater for 4 hours. The diver or 'Iron Mike' communicated with the ship's crew on the surface with the aid of a telephone.

Chester Headliffe designed a deep sea diving suit, made of aluminium that weighed 250kg. It was not airtight, so the diver had to expel the water from inside it with the help of a special pump. The air was supplied from the surface.

A German firm called Neufeldt & Kuhnle created a whole series of underwater diving suits that were improved and perfected over the years.

Engineer and submarine builder, Lederer Phillips designed an underwater costume made out of a steel cylinder. No one knows if his design was ever produced or if anybody tried diving in it.

The diving suit invented by Australian John Buchanan and John Wainman was made of flexible waterproof material, stiffened by a metal construction.

The Tritonia was Joseph Salim Peress's next diving suit. It worked perfectly in Loch Ness at a depth of 125m, and then off the Irish coast, where the inventor's assistant, drowned in it to the wreck of the steamship *RMS Australic*.

Inventor John Leithridge used his own legs to support his suit in the shape of an oak trunk. He analysed a large number of sunken ships. He was the first to make a large foraine in the process, diving to depths of 200 metres in his barrel.

Captain Sydney Hill and surgeon Oswald Rees invented a costume that was designed to enable safe escape from a sinking submarine. They sank down in a holding tank, constructing a mechanism that would allow the use of the same small amount of oxygen. The carbon dioxide exhaled by the diver was absorbed by sodium peroxide, which as a result of this reaction produced oxygen again.

Charles Peccout de Fluy invented a diving suit that contained carbon dioxide and produced oxygen. He dived to a depth of 50m in it.

1808
A simple diving suit made of animal skins and a wooden barrel for breathing apparatus.

1894
A diving suit made of iron plates and a wooden barrel for breathing apparatus.

1797
A simple diving suit made of animal skins and a wooden barrel for breathing apparatus.

1715
A simple diving suit made of animal skins and a wooden barrel for breathing apparatus.

1715
The first helmet was designed for walking on over rocks. He tested it in his own cell of the River Oise.

1916
A diving suit made of animal skins and a wooden barrel for breathing apparatus.

1806
A simple diving suit made of animal skins and a wooden barrel for breathing apparatus.

boots weighted with lead

used air

RECORD-BREAKING DIVERS

Myrlean Sea, Greece

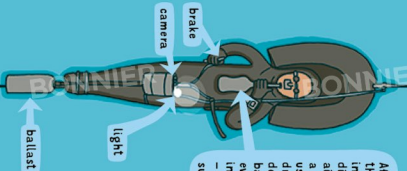
2007

Herbert Nitsch, freediving world record holder, can hold his breath for over 9 minutes!

He dived to a record depth of 214 metres off the Greek island of Speles. The dive down and back took him 4 minutes and 26 seconds.

He used a special lift that moves at a speed of 3–4 metres per second.

After breathing in at the surface in the initial phase of the dive, the diver fills a plastic bottle, like an ordinary empty drink bottle. At greater depths he draws it back into his lungs to rein out the pressure – otherwise they could suffer an injury.



Five years later Herbert tried to break his own record by diving to a depth of 253 metres. Unfortunately on the way back up he had a decompression sickness (see pages 12–13) and had to be helped by other divers.

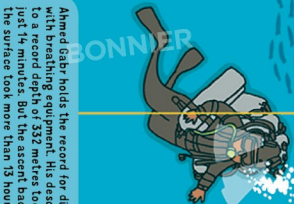
New lift
Best diving
team
to break the
record.

Any diver aiming to break the world record for the deepest dive without breathing equipment has very little time to do so in the freediving discipline known as no limits apnea: special lifts are used to descend deep underwater, as fast as possible, while using up as little energy as possible.



Gulf of Aqaba, Red Sea, Egypt

2014



Ahmed Gabr holds the record for diving with breathing equipment. His descent to a record depth of 332 metres took him just 14 minutes, but the ascent back to the surface took more than 13 hours.

To avoid decompression sickness caused by diving too deep, Ahmed stopped more than 50 times on the way back up.

When he was only 3 metres underwater, he had to stop for another 2 hours to allow his body to adapt to the change of pressure.

During his almost 14-hour dive Ahmed used several dozen cylinders of gas for breathing. He had nine of them with him from the start, and the rest were supplied to him by scatted divers on his team, who looked after his safety.

At great depths Ahmed did not breathe oxygen, nitrogen and helium.

During record-breaking attempts the divers descend to the depth of 332 metres with weight-tape with depth markers fastened to it. The markers unfastened by the diver are one piece of evidence to show how deep he or she went underwater. Ahmed made his ascent 335 metres. As a result of the current had bent the rope, raising the marker to a slightly lesser depth.

Pacific Ocean, California, United States

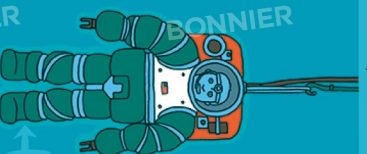
2008

For working at very deep depths, special atmospheric diving suits are used which, like a hard airtight diving suit, protect the diver from the high pressure prevalent underwater. The pressure inside a suit of this kind is always the same as on the surface, so that the diver can ascend at any speed, without time-consuming decompression.

Repairing oil platforms (see pages 30–31) or rescue missions following submarine accidents are the most common uses of the use of equipment of this kind.

American navy diver Daniel Jackson descended in an aluminium atmospheric diving suit to a record depth of 510 metres. He achieved this record while wearing a special diving suit – such a deep descent would not have been possible in earlier models.

The diving suit Daniel Jackson dived in is equipped with a drive that enables it to move upwards, downwards and sideways. The air supply is enough for an 8-hour mission. The diver has oxygen tanks on his back. He can use numerous tools, and also has still- or video cameras at his or her disposal.



atmospheric
diving suit
ADS 2000

-214m

-332.35m

-610m

Free diving is diving while holding your breath. Trained divers can hold their breath underwater for several minutes.

Diving just below the surface of the water with a breathing tube, a mask and fins is called snorkelling. Thanks to this tube, you can admire the underwater world without having to take breaks to put your head above water.

A rubber hose connects the diver with the surface and supplies air.

A scuba diver carries a cylinder of compressed air to breathe, and the surface on land has to breathe. The cylinder makes it possible to dive deeper for longer, and the tube either

A diving bell is an invention that was first used in ancient times. Over the centuries, it has been changed and perfected. It has the same principle as a diving bell, but the principle of it is the same. The ball opens from underneath, so when it is lowered under the water, air is trapped inside, which the diver can breathe. Nowadays diving bells are used as underwater lifts to help divers to reach the bottom. Divers to reach the bottom once underwater, but they are connected to it the whole time by tubes that supply air.

Helmet, into which the air is fed with the aid of cables connecting the diver to the ship or the shore.

man's rag

spare gas cylinder

These cables guarantee the diver contact with the surface and are used to send information about the dive depth and pictures from the helmet.

spare gas cylinder

For some people, diving is a form of relaxation, and for others, it is their daily job. Many of the tasks to be performed at all platforms (see pages 30-31) can only be done by specialised, professional divers.



We carry a pillar of air above us



The Earth's atmosphere, which is the layer of air surrounding our planet



Although we do not usually notice it, air has its weight too. It is constantly pushing down on us and on everything else on Earth. We call this force **pressure**.

Pressure is lower in the mountains because the pillar of air above us is shorter, and so weighs less.



If we fill a balloon with a gas (lighter than air, for example, helium) ① and let it fly upwards, the balloon will grow bigger as it gains height. ②



That happens because the higher you go, the lower the air pressure. This means that the air is pressing less and less hard on the balloon, so the gas squeezed into it can stretch out more and more. ③

underwater

The changes in air pressure at different heights are small compared with how quickly the pressure increases underwater.

A gas-filled balloon immersed in water shrinks greatly. ① The deeper below the surface, the harder the water presses on the outside of the balloon. ②

As the depth increases, the balloon will shrink, more and more, until the pressure of the gas inside it is equal to the pressure of the water around it. ③

This is why submarines have to be made out of materials that can withstand the immense water pressure at great depths. If the air is too weak, the crew will be crushed inside the submarine like the air inside the balloon.

The pillar of water above the diver pushes down more forcefully than a pillar of air would do.

Water is far heavier than air, so the diver starts to descend, the amount of water above him or her gradually increases, and he or she quickly starts to feel the growing pressure.

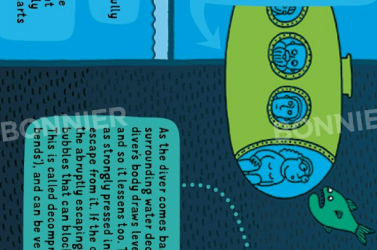
The air pressure in the divers' lungs draws level with the pressure of the surrounding water. That is why it is greater than at the surface.



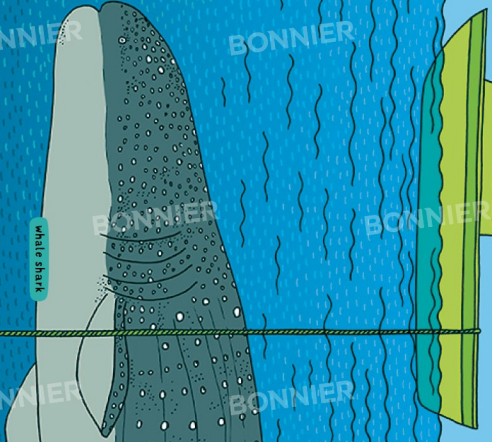
If you only dive to shallow depths, pressure is not a big problem, but if a diver spends a long time deep underwater, the air in his or her lungs has to go through a special process called **decompression**.

The air pressure in the divers' lungs draws level with the pressure of the surrounding water. That is why it is greater than at the surface.

Air is a mixture of gases, consisting mainly of nitrogen and oxygen. When a person inhales on the surface, he or she uses part of the oxygen, and then exhales all of the nitrogen. But underwater, under high pressure, some of the nitrogen is pushed into the blood. The deeper the diver descends, the more of this gas will end up in his or her body.



As the diver comes back up, the pressure of the surrounding water decreases. The pressure in the divers' body stays level with the water pressure, and so it doesn't rise. The nitrogen is no longer to escape from it. If the diver comes up too quickly, the abruptly escaping nitrogen changes into bubbles that can block the diver's blood vessels. This is called **decompression sickness** (or 'the bends'), and can be very dangerous.



whale shark



But there's a big problem with it. If the diver descends several fathoms on the way, his or her body has time to adapt to the changing pressure. This usually and gradually escapes from the blood, and the diver will have no problems reaching the surface. This method of stopping the diver's body from being crushed up is called **decompression**.



SPECTACULAR SINKHOLES

Visible from a plane, a round, dark patch in the bright blue sea shows where there is a deep hole in the seabed.

These underwater pits are to be found in many places all over the world, usually close to the shoreline. They can have a diameter of several hundred metres and a depth of over 100 metres.

There are many similar, or even bigger, sinkholes in the ground, on land as well as at sea.



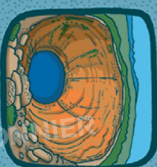
The Great Blue Hole is 127m deep and attracts divers from all over the world. It is in the middle of a coral reef off the coast of Belize.



Dean's Blue Hole in the Bahamas is the deepest in the world. Its bottom lies at 202m below sea level. Many records for deep diving have been broken here.



This underwater sinkhole in the Red Sea near the Egyptian town of Dahab is famous as a beautiful but dangerous place for diving. It is 150m deep, and 3m below the surface it has a 'perfect' sun light picturesque tunnel.



Red Lake in Croatia is situated in a large sinkhole at a depth of 520m.



Dashiwu Tiankeng is a gigantic sinkhole in China. It is 31m deep and is a perfect right round. If you have to go more than 15km, its bottom is overgrown with a forest full of rare plants and animals.



Sima Limboldt is a sinkhole 37m deep, that has a big table in the middle that is as flat as a table. It is in Venezuela.



In 2007 the earth collapsed and the sinkhole opened up a hole 100m deep.

On land, deep holes in the ground can unexpectedly appear, in the middle of nowhere, or in the centre of a city. Sometimes houses and cars are swallowed up along with the collapsing earth.

It happens suddenly but the process that leads to the ground collapsing takes a long time and starts much earlier. Sinkholes are caused by water flowing under the ground, which gradually hollows out rocks, creating underground caves.

On the surface, nobody suspects that just a few metres below, instead of a hard foundation there is an empty space – a cave that keeps increasing in size, until finally its roof cannot hold out and it collapses, revealing an enormous hole.

Underwater sinkholes in the seas and oceans came into being thousands of years ago in a similar way to the ones on land. To begin with they were not underwater, because the sea level was much lower when they were created.

CORAL REEFS

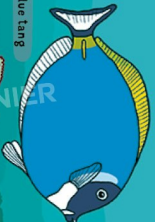
In the shallow, sun-drenched waters of warm seas we find one of the natural world's most precious treasures – the coral reef. Coral reefs are made up of rocks formed from the remains of coral and covered with living colonies of them. They exist at a depth of up to 50 metres in places where the temperature of the water never falls below 16°C.

The corals that build the reefs are tiny animals that live in long, thin tubes. They create immense colonies of various colours and shapes, made up of many thousands of individuals. Although they resemble plants, they are animals. They feed mainly on zooplankton (microscopic sea creatures). In addition, there are the 'brain corals' that store the sunlight to produce nutrients for them.

Coral reefs are the focus for a great wealth and variety of underwater nature. Although they only occupy a fraction of a percent of the surface of the oceans, as many as 25% of all species of sea creatures live in and around them: rainbow-coloured fish, sea turtles, sharks, squid, octopus, damselfish, sea urchins and many, many others.



whale shark



powder blue tang



Pomacentrus tringoides



bluelined butterflyfish



empress angelfish



yellow tang



green chromis



saddleback clownfish



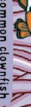
schooling bannerfish



bicoloral numb



orange-lined triggerfish



common clownfish



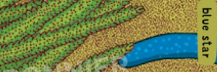
copperband butterflyfish



Barrier Reef anemonefish



blue surgeonfish



blue star

-50m

WHAT FLOATS, WHAT SINKS?

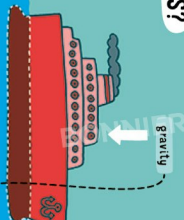
The answer seems simple – don't light things stay on the surface and heavy things go to the bottom? But is that really true? If that is the case, why don't ships weighing many tons sink? And why can submarines sail under water without cropping onto the seabed or bobbing up to the surface?

Whenever we dive into water, we are affected by a force called buoyancy. It is a force that pushes us upwards and keeps us out of the spaces we have taken away from it. While the force of gravity pulls us towards the ground, the force of buoyancy pushes us vertically upwards. Staying afloat depends on correctly balancing these two forces.

a diver

If divers had no extra load, buoyancy would constantly be pushing them up to the surface. That is why part of a diving costume is a specially weighted ballast belt, which makes it easier to plunge underwater.

Underwater, divers can change the dive depth with the help of a special jacket. If the diver lets air into it, he or she will float upwards. If the diver lets air out, he or she will drop towards the seabed.



The ship has pushed out – or displaced – this much water.

The ship floats if these two forces are even, in other words, the weight of the ship pulls it down, and the same force as the water exerts to push it up to the surface.

On his or her back, a diver has a cylinder full of compressed air to breathe. The air used to fill the jacket also comes out of it.



Divers can also adjust the dive depth using breath. A deep inhalation fills the lungs with air, so the diver is able to rise slightly above the surface. After a deep exhalation, divers will go deeper again.

Thanks to buoyancy we feel lighter in water. The diving equipment also feels much heavier on land than after diving underwater.

a submarine

Submarines dive down and resurface with the help of ballast tanks and also diving planes.

Ballast tanks are chambers that can be filled with water, air, or a bit of both, depending whether the submarine is to dive, surface, or remain at a stable depth.

Most fish have a swim bladder, which helps them to change their dive depth. It is a special sac that the fish can fill with a gas that is lighter than water – usually oxygen.

In some species, the swim bladder is connected to the alimentary canal. Fish of this kind can simply swim up to the surface of the water and swallow a little air, which then ends up in the swim bladder.

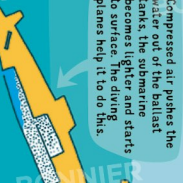
In other species the oxygen is fill the swim bladder comes directly from the blood, with the help of a special gland.



1 The submarine takes water into the ballast tanks and changes the position of the diving planes. As a result, it descends deeper and deeper underwater.



2 When the tanks fill with water, the submarine becomes heavier.



3 Compressed air pushes the water out of the ballast tanks, the submarine becomes lighter and starts to surface. The diving planes help it to do this.

The diving planes are the submariners' fins. Their position determines whether it sails upwards, raises its bow and dives deeper, or else moves at a stable depth with its bow in a horizontal position.

a fish



Most fish have a swim bladder, which helps them to change their dive depth. It is a special sac that the fish can fill with a gas that is lighter than water – usually oxygen.

When the swim bladder is full, the fish displaces more water, so buoyancy pushes it upwards more forcefully and it is easier for it to surface.



To dive deeper, the fish empties the swim bladder.



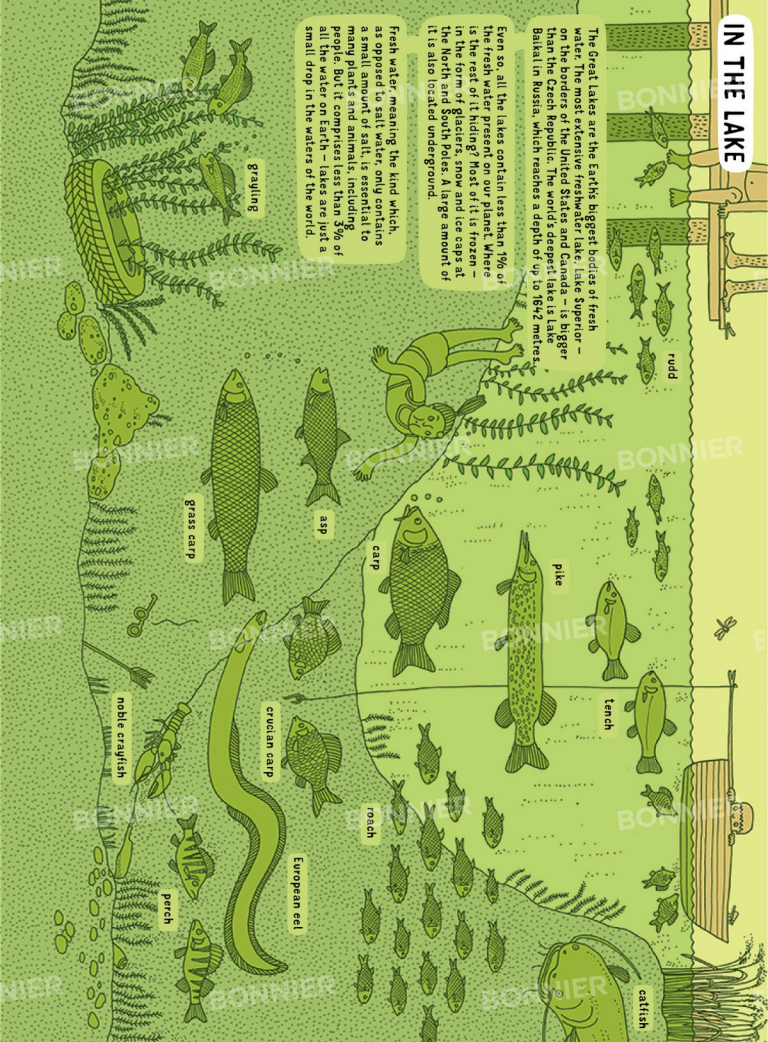
The gas is expelled from the swim bladder in the same way it arrived – some species release it into the water through the mouth, others pump it back into the blood.

IN THE LAKE

The Great Lakes are the Earth's biggest bodies of fresh water. The most extensive freshwater lake, Lake Superior – on the borders of the United States and Canada – is bigger than the Czech Republic. The world's deepest lake is Lake Baikal in Russia, which reaches a depth of up to 1642 metres.

Even so, all the lakes contain less than 1% of the fresh water present on our planet. Where is the rest of it hiding? Most of it is frozen – in the form of glaciers, snow and ice caps at the North and South Poles. A large amount of it is also locked underground.

Fresh water – meaning the kind which, as opposed to salt water, only contains a small amount of salt, is essential to many plants and animals. In fact, 99% of all the water on Earth – lakes are just a small drop in the waters of the world.



rodd

pike

tench

perch

carp

roach

asp

European eel

grass carp

perch

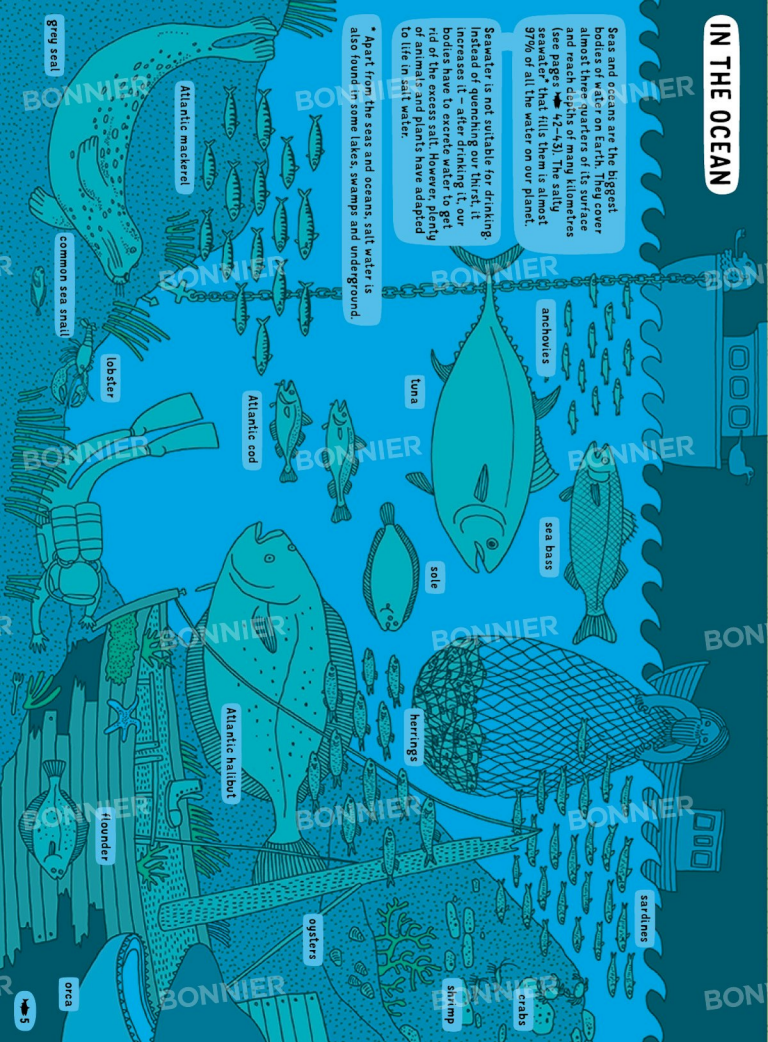
noble crayfish

IN THE OCEAN

Seas and oceans are the biggest bodies of water on Earth. They cover almost three quarters of its surface and reach depths of many kilometres (see pages 42–43). The salty seawater that fills them is almost 97% of all the water on our planet.

Seawater is not suitable for drinking. Instead of quenching our thirst, it increases it – after drinking it, our bodies have to excrete water to get rid of animals' and plants' have adapted to life in salt water.

* Apart from the seas and oceans, salt water is also found in some lakes, swamps and underground.



anchovies

sea bass

sole

tuna

herring

oysters

Atlantic cod

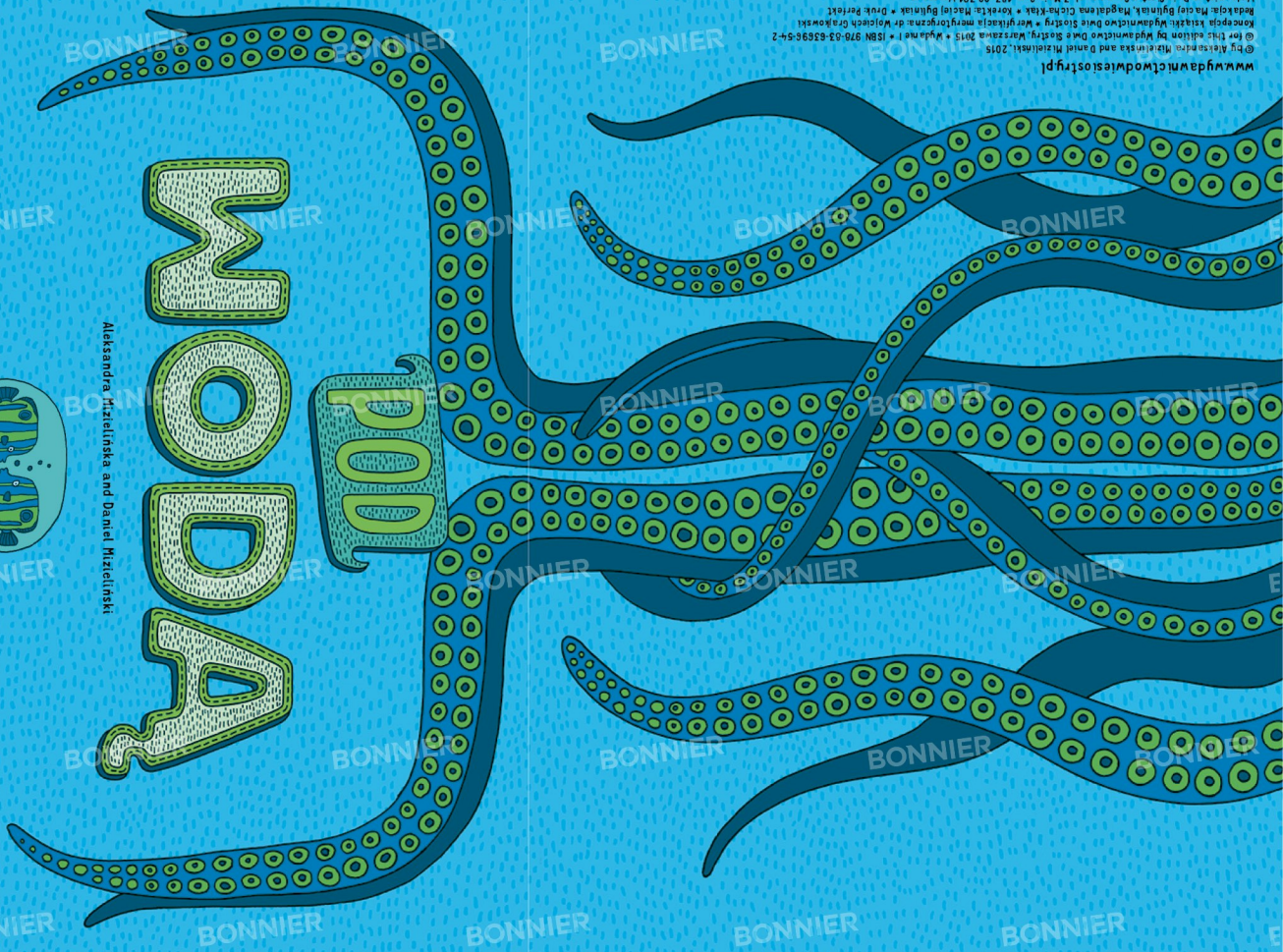
Atlantic halibut

Atlantic mackerel

lobster

common sea snail

grey seal



WODNA

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DISCOVER THE SECRETS OF THE UNDERWATER WORLD

This book will take you on an unusual journey into the depths of the seas and oceans. There you will meet record-breaking divers and scientists in research vessels. You will come across fabulously colourful fish, giants of the sea and weird creatures of the deep. You will test-drive some vintage submarines, dive in an undersea well and explore the wreck of the *Titanic*. Huge illustrations and detailed cross-sections will guide you deeper and deeper down, from coral reefs bathed in sunlight to the deepest part of the ocean, plunged in cold and darkness. Go right through them to see what lies hidden... UNDERGROUND.

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