Entrance

Welcome to Oceanarium

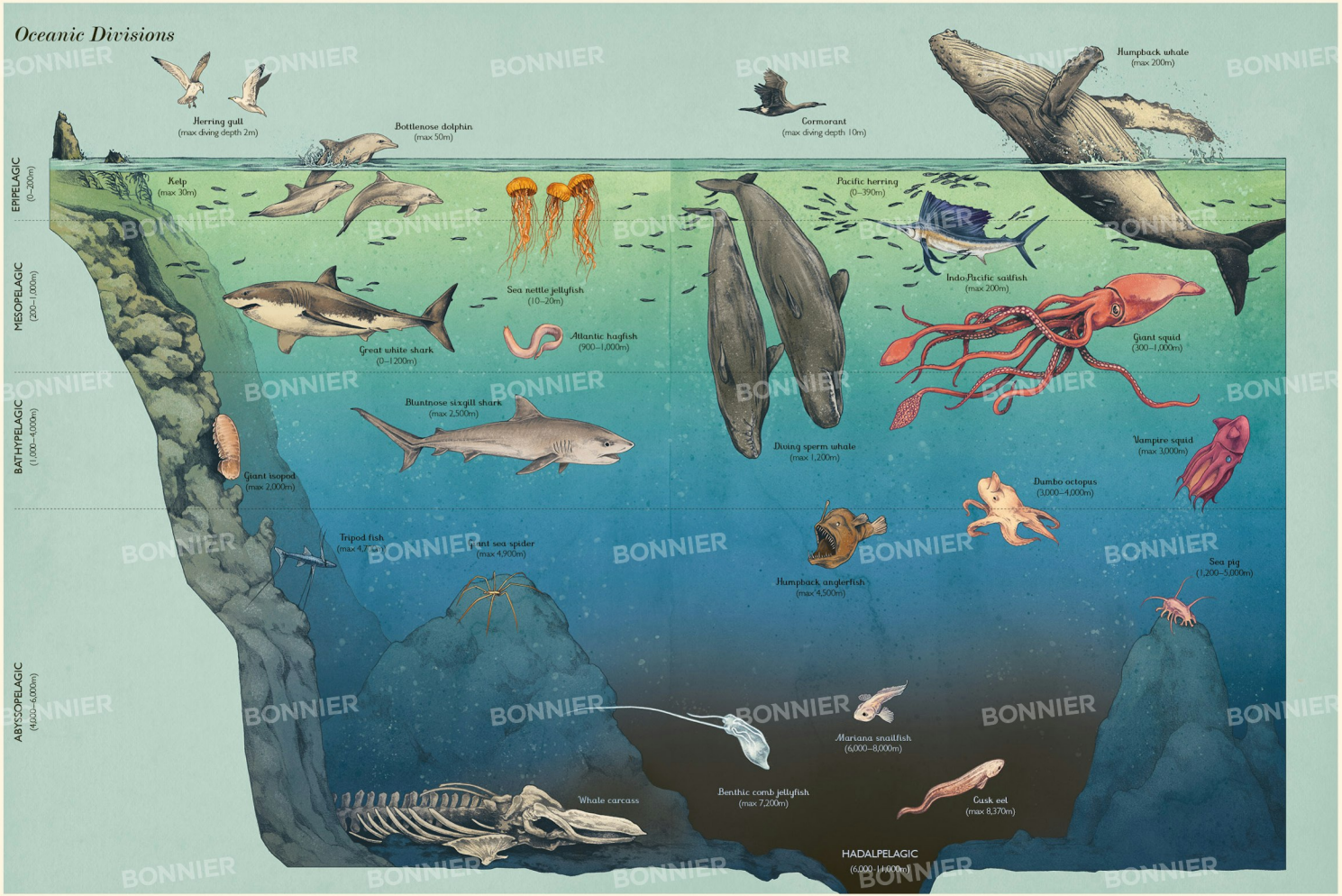
This is no ordinary aquarium. Open twenty-four hours a day, seven days a week, each exhibit showcases the ocean's inhabitants as you have never seen them before. See the world's largest animal, inspect some of the smallest, and marvel at the kaleidoscope of colours, shapes and sizes of life under the water.

Stroll through this book to tour the aquarium, and discover for yourself the majesty that the ocean holds. From the sunlit shallows to the darkest depths, in the pages that follow you will find extraordinary creatures that normally lie hidden beneath the waves.

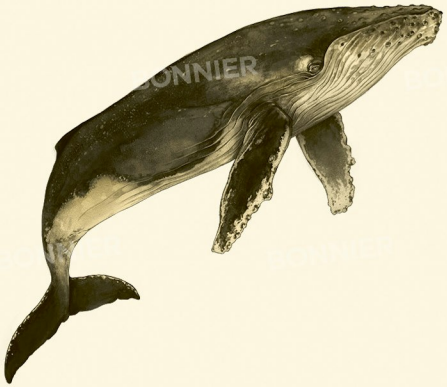
Take a moment to inspect each habitat carefully. You will be amazed at what you find there. There are some species who are nearly as old as life itself, slowly patrolling the open waters in search of their next meal. There are others whose scales glint and shimmer as they dart nervously between corals. Some lie so perfectly still on the sandbed, that you may not notice them at all… and others are magicians, changing colour and form to seemingly 'disappear' in plain sight.

Pass through the aquarium's halls and learn about our precious connection with the ocean, and how its future may well hold the key to our own future. It is in learning how we influence each other, that we can begin to better understand our complex relationship with the ocean and overcome the challenges we currently face.

Enter *Oceanarium* and discover the secrets of the sea for yourself. From the majestic to the peculiar, the fearsome to the vulnerable, this awe-inspiring world is laid before you to explore.



Ocean Zones



When we look out to sea, we are viewing a tiny proportion of what is the most significant feature of our planet. The ocean is millions of times the size of our view of the horizon and, with an average of nearly four kilometres of water below the surface, diving beneath the waves reveals a world unseen by most people.

The ocean is the largest habitat on Earth and its scale is difficult to imagine – the tallest feature on land, Mount Everest, could fit inside the 11,000-metre-deep Mariana Trench with 2,000 metres to spare. Containing 99 per cent of all the living space available to animals and plants on our planet, conditions change as you descend through the watery depths, leading to the evolution of some of the most incredible species on our planet.

As you plunge from the ocean's surface, sunlight decreases with each metre. The faint light that can be seen at around 100 metres disappears entirely at 200 metres. Seaweeds and other photosynthetic life thrive in this illuminated upper level, supporting a variety of creatures including most marine mammals, sea turtles and fish.

Venturing into the darkness, the pressure begins to intensify. Dive to 1,000 metres (the range at which sperm whales are known to hunt) and the pressure is 100 times greater than on the water's surface – enough to crush most living things which live in shallower water. Even in this most extreme of environments, the flickering glow of bioluminescent species can still be seen, and unique scuttling crabs and graceful jellies swarm around smoking hydrothermal vents – fissures in the ocean floor beneath which red hot magma courses, providing precious sources of food and warm water.

At the deepest zone – the hadalpelagic trenches – the pressure is an incredible eight tonnes per square inch, and temperatures struggle to rise above freezing. It was once thought that no life could possibly exist here, but early explorers Don Walsh and Jacques Piccard disproved this idea when they descended into the Mariana Trench – an almost impossible journey which took them five hours to complete. In this most inhospitable of homes, giant insect-like creatures could be found, scavenging for food fallen from the surface 11 kilometres away.

Oceanarium

Blue Planet

The history of Earth's ocean starts with the beginnings of the universe. This story takes us back 13.8 billion years to the Big Bang, during which vast amounts of hydrogen gas formed. Hundreds of millions of years later, when the universe had cooled, oxygen atoms appeared and it was then that the first water molecules were created in the form of H_2O. Those same water molecules that originated from the universe's tumultuous beginnings are still in existence today. They have floated through our rivers and lakes, passed through living beings from dinosaurs to humans and trees to plants, and have travelled from high in the atmosphere to deep underground.

While many planets and moons have been found to have water in the form of gas or ice, few possess it as a liquid. This is what makes our planet special. Earth is the ideal distance from the sun for water to exist – any closer and temperatures would be too hot, causing it to evaporate, any further away and it would be too cold, causing it to freeze. With a protective atmosphere kept in place by a strong magnetic field, this precious liquid is safeguarded from being lost to space, and is what enables all life forms to flourish.

But there may have been a time when water didn't exist on our planet at all. Some scientists believe that most of it arrived during the early forming of the universe, when asteroids and meteorites containing water crashed down to Earth after hurtling through space. There is also evidence that water in the form of vapour was present in the very early days of our planet and, as it cooled, it condensed and fell as rain. Centuries of rainfall may have filled enormous craters on our planet and they remain full to this day.

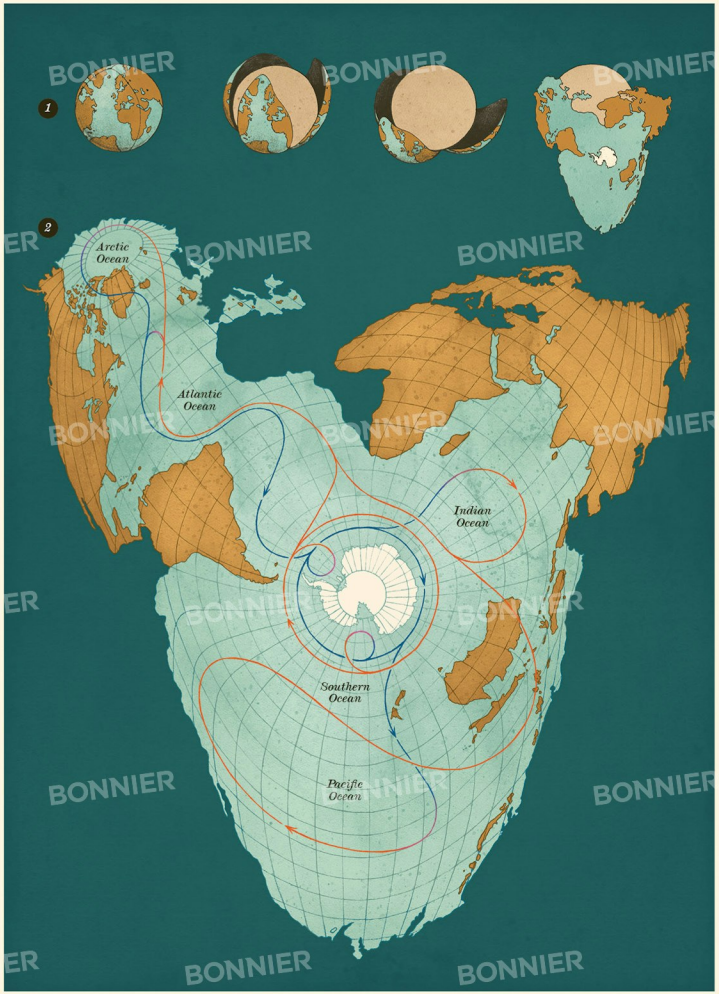
The ocean has not remained the same shape since those early days. The land was once connected as one giant supercontinent known as Pangaea and similarly the ocean would have existed as one enormous basin. In the unimaginably long stretches of geological time since, land masses have changed, breaking apart as the planet's crust collided and shifted. The ocean also moved but, unlike the land, remained connected. Today, it is possible to travel around our whole planet without touching land once – a journey of around 50,000 kilometres.

We have come a long way since then. Our ocean today is estimated to contain around 1.3 billion cubic kilometres of water and is teeming with life. It is the most defining hallmark of our planet, covering over 70 per cent of Earth's surface. From space, it is clear just how much this incredible feature characterises our home, giving rise to Earth's fondest epithet, the Blue Planet.

Key to plate

1: **Spilhaus divides**
This series of globes show where Spilhaus interrupted the land to depict the ocean as a whole.

2: **Spilhaus projection with ocean currents**
Created by Dr Spilhaus in 1942, this map shows the ocean as one continuous body of water. Unlike a traditional world map, Spilhaus's focuses on Earth's water distribution and displays it as a prominent feature. The currents in the ocean are driven by water at different densities. Cold, salty water is dense and sinks, whereas warm, fresher water is lighter and floats. The arrows on the map show where the deep cold currents (blue) and the warm surface currents (red) are. These currents carry not only water around the planet but also energy, which influences our weather and climate.



For all my friends at the NMA and for Isabella and Charlie, future ocean optimists – L.T.

For Arcadia Beach – T.W.

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NMA NATIONAL MARINE AQUARIUM

FSC

Welcome to the Museum

ADMIT ALL

Oceanarium

Illustrated by TEAGAN WHITE

Written by LOVEDAY TRINICK

BPP

Gallery 1

Plankton

Phytoplankton
Zooplankton

Preface

Viewed from space, Earth's blue surface is dominated by water. This makes our planet different from every other in the solar system, and potentially unique in our universe. It is because we have water, that life can exist.

The ocean supports all life, both under water and on land – influencing our climate, dictating our weather patterns and providing half of the oxygen we breathe. Yet despite being so important, humans have only explored a tiny proportion of the ocean and new discoveries are found every time we venture into the deep.

Many scientists believe that life on Earth began in the ocean, overcoming cataclysmic asteroid strikes and toxic conditions, to later emerge on land. From these microbial life forms evolved every type of creature we see above ground today. Living things continued evolving underwater too, responding to changes in their environment to create an explosion of diversity, capable of thriving in every type of habitat. Today, we know of around 230,000 species of animals and plants in the ocean, but it is thought that there could be as many as two million yet to be discovered.

As fast as we are finding new life, however, we could also be losing it. With human impact such as climate change and pollution driving this loss, it is more important than ever to learn, explore, enjoy and protect this precious resource, not only for the life we find there but for our future generations. It is only when we begin to understand the wonder of this wild habitat, that we can appreciate its role in our lives.

Loveday Trinick
The National Marine Aquarium

Phytoplankton

The ocean is home to some of the smallest and biggest creatures that have ever lived. Among the smallest are plankton – microscopic organisms that drift through the sea as nomads, carried by the ocean currents and unable to swim against them. Plankton are so small that most are measured in micrometres (μm) – one centimetre is the equivalent of 10,000 micrometres.

Some plankton behave a little like plants and are known as phytoplankton. Just like flora on land, phytoplankton can make their own food via photosynthesis. Oxygen is made as a by-product of this process, and scientists estimate that around half of the oxygen in Earth's atmosphere was made in the ocean by plankton. It is because of this ability to photosynthesise that phytoplankton are primary producers, positioned at the bottom of the food chain in the ocean. They are vitally important because they support a whole ecosystem, providing food for many ocean animals, from tiny animal plankton to giant whale sharks.

Because they need sunlight to photosynthesise, phytoplankton must stay near the ocean's surface. With more sunlight encouraging reproduction during the spring and summer months, phytoplankton can occur in large numbers at this time, known as blooms. These natural occurrences fuel explosions of life in the ocean, but too much phytoplankton can be damaging. Known as harmful algal blooms, these dangerous swellings can create toxins and deplete oxygen levels, resulting in areas known as 'dead zones' where marine animals and plants are unable to survive. This can be caused when fertiliser washes off farmland and into the sea, rapidly increasing growth, and is a reminder that the sea is not immune to our activities on land.

Key to plate

1: **Cyanobacteria**
Prochlorococcus marinus
Diameter: Approx. 0.6μm
This minuscule plankton is one of the most abundant photosynthetic organisms on Earth. One millilitre of seawater can contain around 100,000 *P. marinus* cyanobacteria.

2: **Dinoflagellate**
Ceratium ranipes
Diameter: Up to 200μm
During the day, this dinoflagellate extends its 'fingers' into the water. These contain chloroplasts which are used in photosynthesis.

3: **Diatom**
Ditylum brightwellii
Length: Up to 300μm
This diatom is a tiny, single-celled algae that makes its body out of glass-like silica – meaning it effectively lives in a glasshouse.

4: **Coccolithophore**
Emiliania huxleyi
Length: Approx. 5μm
Coccolithophores have a covering of chalky discs, which reflect sunlight. When *E. huxleyi* blooms, this reflection of light is visible to satellites in space.

5: **Sea sparkle**
Noctiluca scintillans
Diameter: Up to 2,000μm
This species makes light via bioluminescence when disturbed, producing an ethereal blue-green glow.

6: ***Chaetoceros debilis***
Length: Up to 20μm
These microscopic algae join together to form long, spiral-shaped chains.

Zooplankton

A group of mainly microscopic creatures, tiny zooplankton drift on the ocean currents. Some of them are the larvae of animals, and will grow and eventually mature into crabs, fish and other recognisable sea creatures, while others, such as copepods, will remain minuscule organisms their whole lives. Floating by the thousands in every drop of water on the ocean's surface, they form a 'soup' full of life together with phytoplankton, which will ultimately feed almost every other animal in the ocean.

Both phytoplankton and zooplankton play an important role in ocean food chains. While phytoplankton use the sun's energy to make food, zooplankton provide the link between phytoplankton and larger sea creatures. Some are herbivorous, grazing directly on phytoplankton, while others are predatory and hunt for smaller zooplankton. Many are eaten by larger animals – blue whales can consume as much as four tonnes of krill in a single day (see page 62).

Meroplankton are the larvae of animals, such as crustaceans and cnidarian, that sink from the ocean's surface when they are grown, to live in a variety of habitats, from coral reefs to the deep sea. Larvae will often look very different to the adult that they will become – ocean sunfish young, for example, are only two millimetres in length and are covered with spines, while adults lose their spines and can grow to nearly two metres.

Despite their minute size, zooplankton travel from the ocean's surface to the murky depths and back again every day. This is called vertical migration and it allows them to feed on phytoplankton in the surface waters at night, avoiding predators that cruise there during the day. With trillions of these animals completing a daily round trip of around 2,000 metres, this represents one of the largest migration events on Earth.

Key to plate

1: **Sea butterfly**
Limacina helicina
Shell width: Up to 6mm
This tiny snail is particularly important to one sea slug called a sea angel which feeds almost exclusively on it.

2: **Polychaete worm**
Tomopteris sp.
Length: Up to 50mm
Some tomopteris worms make yellow bioluminescence, a rare colour in the deep sea.

3: **Starfish larvae**
Asterias sp.
Length: Approx. 1mm
These larvae eventually get too heavy and sink to the seabed. At this point they start to develop into more mature-looking starfish.

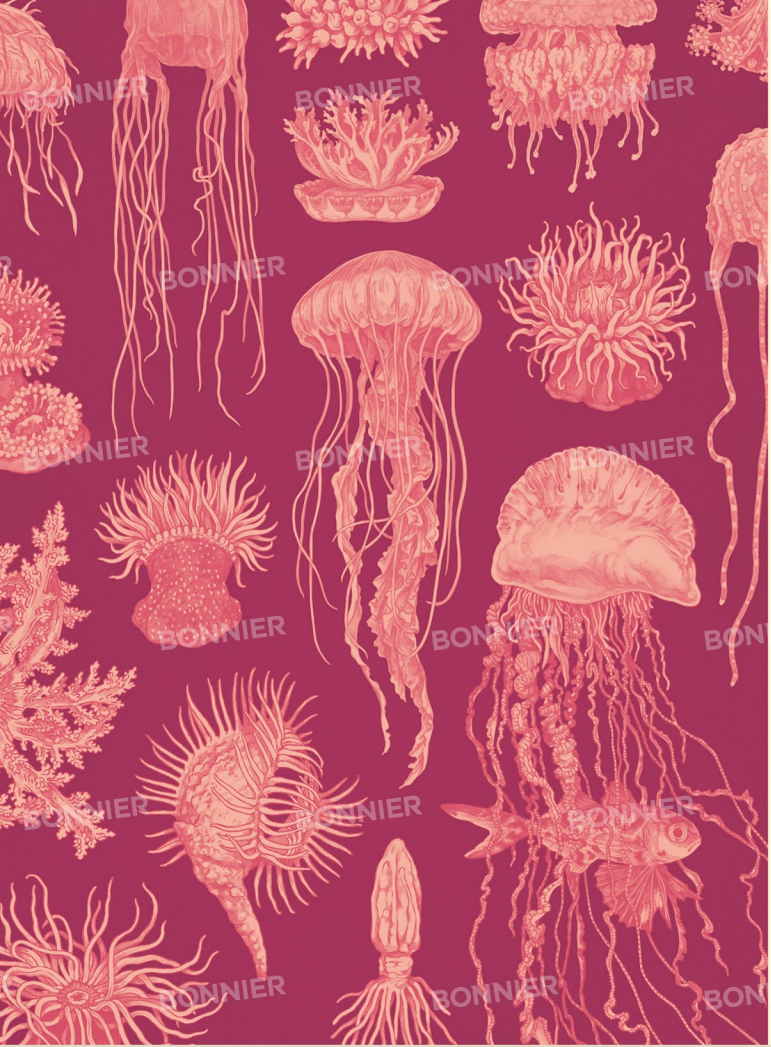
4: **Copepod**
Calanus glacialis
Length: Up to 5.5mm
There are around 13,000 species of copepod. This species lives in the Arctic, and swims between the ocean's surface and up to 1,800 metres deep.

5: **Green shore crab larvae**
Carcinus maenas
Length: Up to 4mm
Animals that inhabit the seafloor, such as this crab, benefit from having planktonic young, as the larvae can drift vast distances before settling.

6: **Swordfish larvae**
Xiphias gladius
Length: 4mm when newly hatched
As an adult, this highly recognisable predator reaches around 3m long.

7: **Sunfish larvae**
Mola mola
Length: Approx. 2mm
The difference in size between the larvae and the adult is one of the biggest known, meaning they grow more than any other animal on Earth.

8: **Antarctic krill**
Euphausia superba
Length: Up to 6cm
By weight, these little crustaceans are likely to be the most abundant animals on Earth.



Gallery 2

Cnidaria

Jellyfish
Portuguese Man o' War
Anemones
Habitat: Coral Reef

Jellyfish

Jellyfish are wanderers of the ocean, drifting with the currents wherever the water takes them. Despite their name, they are not fish at all as they lack a skeleton, making them invertebrates. Their soft, bell-shaped bodies are around 95 per cent water and contain neither brain nor heart. Without a skeleton, they have only limited movement, but can propel themselves gently through the water by filling their body (the bell) with water, and squeezing it back out again.

Along with coral and anemones, jellyfish belong to the phylum Cnidaria, all of which have stinging cells used to catch prey and provide defence. Most jellyfish have long tentacles, which are lined with cnidocytes, and dangle them into the water beneath them to catch prey. Each cnidocyte consists of a coiled, harpoon-like sting, which fires venom into the victim the moment they brush against it. Several species are translucent, meaning other animals will not see the danger ahead until it is too late, whereas others use bright colours to attract prey. For instance, flower hat jellyfish have fluorescent-tipped tentacles, which may look like green algae to unsuspecting fish. The fish approach the tentacles in the hope of food, but instead swim into a fatal trap. Incredibly, some animals seek out these tentacles intentionally, with juvenile fish and crabs sometimes taking shelter within them as a means of avoiding predators. They rely on a thick mucus coating to protect them or nimbly dodge the tentacles as they sway in the water.

Jellyfish are known to gather in huge numbers known as blooms. These swarm-like groups occur naturally, but are increasing in their frequency and size every year. In some cases, blooms have been big enough to weigh down fishing nets and sink boats. The rising numbers of blooms could be a result of overfishing. Evidence suggests that when small fish are over-harvested, jellyfish have no competition for food, and quickly reproduce. If overfishing cannot be managed, a jellyfish-filled ocean may be the future for our planet!

Key to plate

1: **Box jellyfish**
Chironex fleckeri
Bell diameter: Up to 35cm
Tentacle length: Up to 3m
Also known as the sea wasp, this species has such a powerful venom that it can kill a person if untreated.

2: **Lion's mane jellyfish**
Cyanea capillata
Bell diameter: Over 2m
Tentacle length: Up to 37m
This is the largest known species of jellyfish.

3: **Common kingslayer**
Malo kingi
Height: Approx. 3cm bell
Tentacle length: Up to 100cm
This tiny box jellyfish is highly venomous and its sting can be fatal.

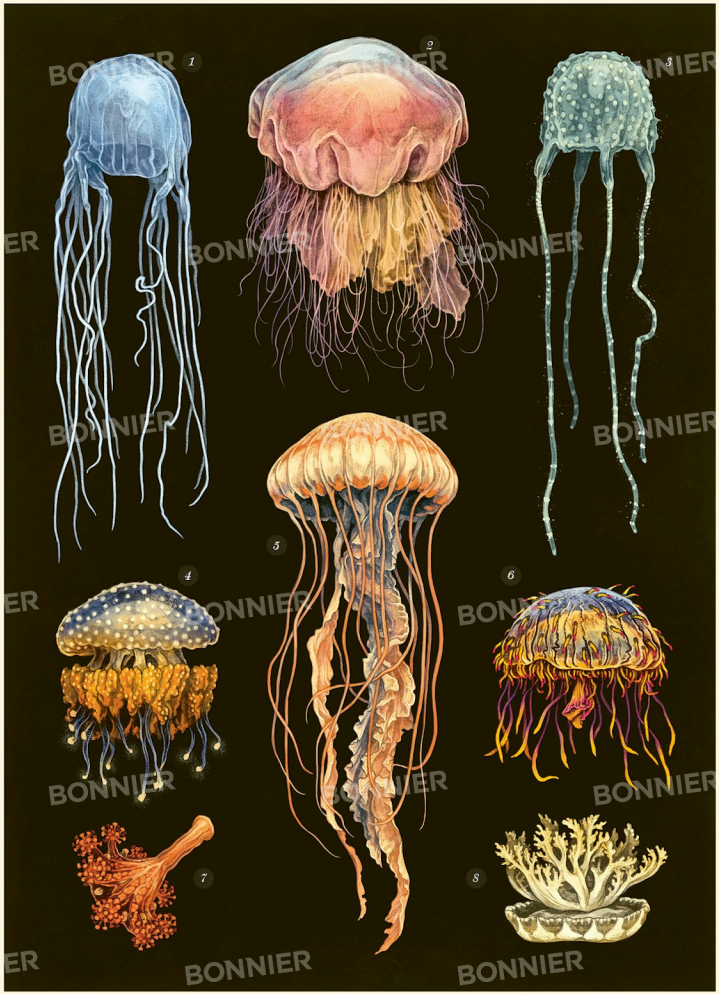
4: **White-spotted jellyfish**
Phyllorhiza punctata
Bell diameter: Up to 5cm
Tentacle length: Up to 1cm
Native to Australia and Japan, this species has been accidentally introduced to other areas including Hawaii and Mexico.

5: **Pacific sea nettle**
Chrysaora fuscescens
Bell diameter: Usually less than 50cm
Tentacle length: Up to 4.5m
Sea nettles provide shelter for young fish and crabs.

6: **Flower hat jellyfish**
Olindias formosus
Bell diameter: Approx. 15cm
This species lives near the seafloor and has tentacles all over its bell (body).

7: **Kaleidoscope jellyfish**
Halclystus auricula
Height: Up to 2.5cm, including tentacles
This stalked jellyfish spends its whole life in one place, attached to seagrass or seaweed by its slender stalk.

8: **Upside-down jellyfish**
Cassiopea andromeda
Bell diameter: Up to 15cm
Tentacle length: Up to 7cm
This peculiar species sits upside down on the seabed with its tentacles waving above it.



Portuguese Man o' War

The extraordinary man o' war is a peculiar-looking creature. Drifting partially submerged in the water, it moves by catching the wind in its sail-like body which is filled with gas, allowing it to wander wherever the wind and ocean currents take it. Below the tranquil surface, a tangle of stinging tentacles trail up to 50 metres deep. This colonial creature is found throughout the world's warmer ocean regions and has been observed in groups of around 1,000 individuals.

Although similar in appearance to jellyfish, the Portuguese man o' war is in fact a colony made up of four types of tiny living organisms called polyps. Each polyp type has a role to play and all of them work together to behave as one animal known as a siphonophore. These polyps include: the pneumatophore, or float, which stops the man o' war from sinking; the long tentacles, which provide defence and catch prey; and the digestive polyps, essential for breaking down food. Each man o' war is either male or female and produces either sperm or eggs. When these meet in the water, a new polyp known as a protozooid is formed, which then generates all parts of the colony.

Despite its seemingly peaceful lifestyle, the Portuguese man o' war is a highly venomous predator, with a sting strong enough to paralyse small fish and cause painful welts on human skin. Just like a true jellyfish, the man o' war spends most of its life in open water, but after storms can drift near beaches. Survival is particularly difficult here, because their soft bodies are unable to withstand collisions with rocks and the seabed. It is here, in shallow waters, that people are most likely to come in to contact with this venomous ocean wanderer.

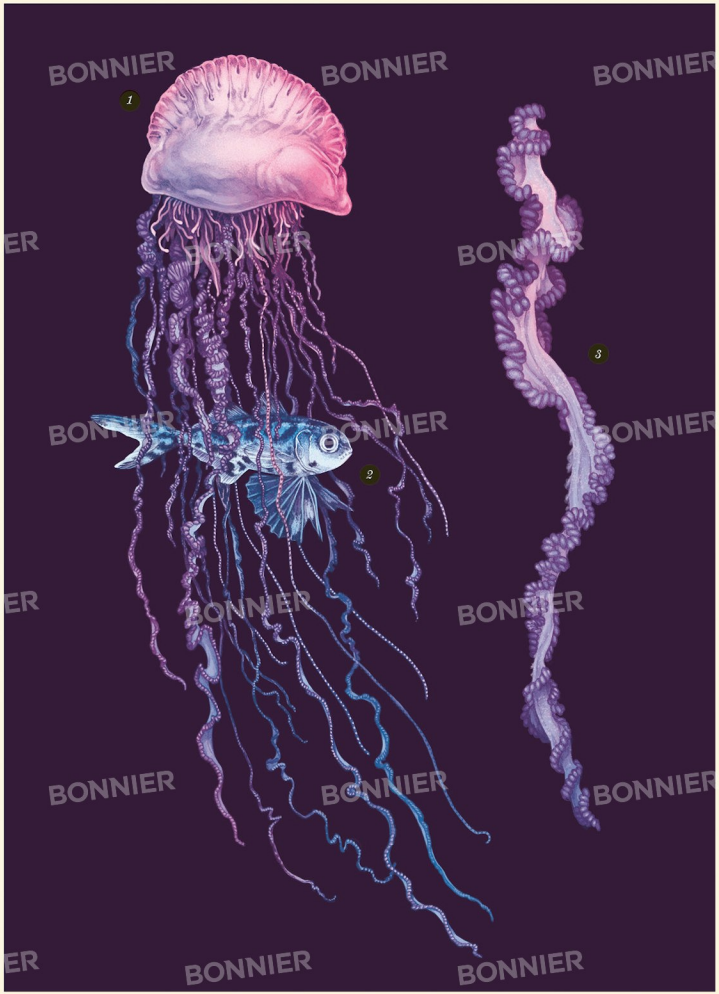
The man o' war does have predators, despite its formidable defences. With thick skin and a tough mouth, loggerhead turtles can consume a whole man o' war in one go, without fear of being stung. The blue dragon sea slug also feeds on the man o' war via a different method. It swims beneath the tentacles, slowly eating them before consuming the pneumatophore. Amazingly, these tiny slugs select the strongest stinging polyps and store them in their own bodies as a defence against predators.

Key to plate

1: **Portuguese man o' war**
Physalia physalis
Pneumatophore length: Up to 30cm
Tentacle length: Up to 50m
The name Portuguese man o' war is thought to come from its resemblance to a Portuguese warship at full sail.

2: **Man-of-war fish**
Nomeus gronovii
Length: Up to 39cm
This small, agile fish manages to live among the tentacles of the Portuguese man o' war. With a higher than usual number of vertebrae, it can twist and turn more easily than other fish, allowing it to avoid the strongest stings.

3: **Close-up of coiled tentacles**
These long, coiled tentacles contain the stinging polyps responsible for catching prey as well as defending the colony from predators. Typically, the tentacles reach around 9m in length, but can grow up to 50m, forming a trap for unsuspecting prey, such as small fish, squid and plankton.



Anemones

With around 1,000 known species worldwide, anemones can be found throughout the ocean, from shallow coastal areas to the deep sea, and even on the underside of Antarctic sea ice. These beautiful creatures spend most of their lives in one place, sticking to a suitable rock with a strong adhesive foot. With their colourful tentacles stretched out in the current to catch food, they can appear to be more plant than animal.

Anemones are carnivores and use their tentacles to sting and catch prey that drift, swim or crawl too close. Similar to other members of their family (such as jellyfish), anemones have cells called cnidocytes that can deliver a sting powerful enough to kill their prey and – in some species – cause a painful rash on human skin. The strength of the sting varies, with some species able to catch and kill tiny plankton and others able to snare larger prey, such as fish.

While anemones' stinging tentacles make them a danger to their prey, some creatures find shelter amongst them. With a thick layer of sting-proof mucus, clownfish live within the bubble-tip anemone where they are safe from predators. In return, the anemone is kept clean by the family of clownfish, who keep it free of parasites. Relationships can exist between anemones and other animals too. The pompom crab picks up and holds tiny anemones in its claws. The anemones are carried by the crab to new areas of the ocean that would otherwise be unreachable, and the crab can wave the anemones at predators to protect itself.

Key to plate

1: **Bubble-tip anemone**
Entacmaea quadricolor
Diameter: Up to 30cm
This beautiful anemone provides a home for clownfish.

2: **Hell's fire anemone**
Actinodendron plumosum
Diameter: Up to 20cm
As the name suggests, this anemone can deliver a painful sting causing skin ulcers in humans.

3: **Jewel anemone**
Corynactis viridis
Diameter: Up to 1cm
These tiny anemones group together and grow in large numbers.

4: **Snakelocks anemone**
Anemonia viridis
Diameter: Up to 7cm
Microscopic algae called zooxanthellae live inside the tentacles of this species, providing its colour and extra food through photosynthesis.

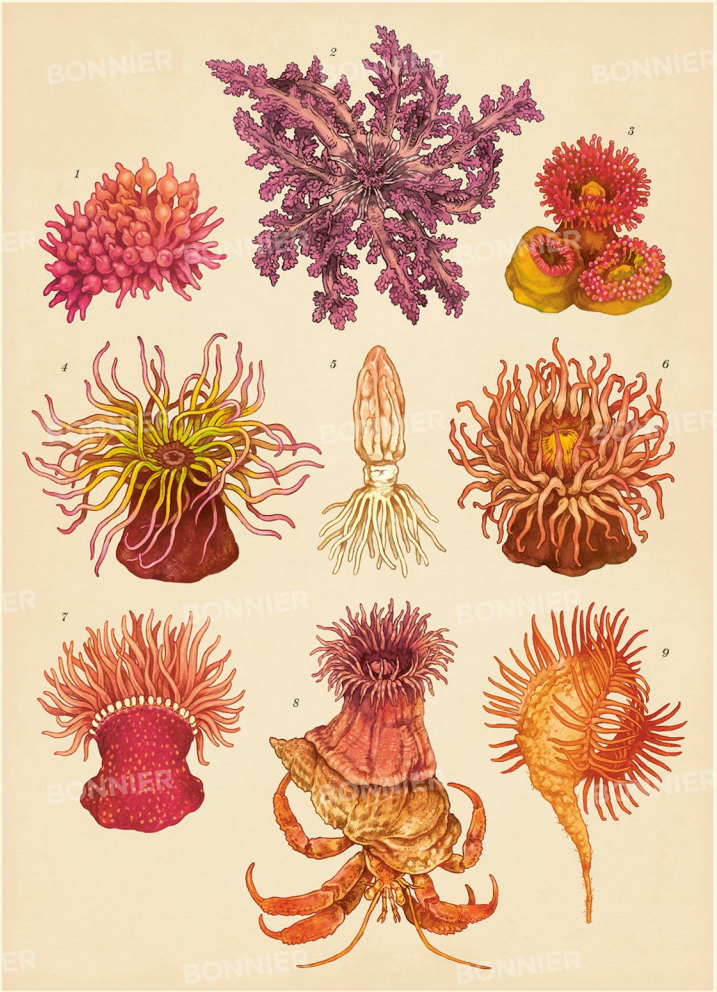
5: ***Edwardsiella andrillae***
Length: Up to 2.5cm
The only anemone to be found living in the ice of Antarctica, it was only discovered by an underwater robot in 2010.

6: **Fish-eating anemone**
Urticina piscivora
Diameter: Up to 25cm
Unlike most other anemones, this species can detach quite easily from rocks and will readily move in search of food or if threatened.

7: **Strawberry anemone**
Actinia fragacea
Diameter: Up to 10cm
This shore-dwelling anemone tucks its tentacles in when exposed to air. This leaves it looking much like a strawberry on the rocks!

8: **Parasitic anemone**
Calliactis parasitica
Diameter: Up to 5cm
Often found living on the shells of hermit crabs, parasitic anemones benefit from a free ride to new areas of food, while the crabs gain protection from the anemones' tentacles.

9: **Venus flytrap anemone**
Actinoscyphia aurelia
Height: Up to 30cm
This deep-sea anemone bears resemblance to the Venus flytrap plant. It uses its long stalk to turn and face the current, making it easier to catch food.



Habitat: Coral Reef

Vibrant and bustling with life, this habitat is like an underwater metropolis, supporting an incredible 25 per cent of marine life worldwide. The animals that live here seek shelter in the reef's nooks and crannies, find camouflage against its bright backdrop, and feast on an abundant supply of food within its colourful corridors.

Coral reefs are formed by coral polyps: tiny animals that resemble sea anemones and live in huge groups called colonies. When they die, the polyps leave behind their hard calcium carbonate (stone) skeletons, and the reef gradually becomes bigger. Coral polyps find food by waving their tentacles in the water to catch drifting scraps. They also take extra nutrients from microscopic algae called zooxanthellae, which live inside the polyps themselves and make food using energy from the sun (via photosynthesis). Zooxanthellae are also what give coral reefs their characteristic bright colours, by producing colourful pigments, and several million can be found in just one square inch of coral. Corals make enormous habitats such as the Belize Barrier Reef in Central America and the Great Barrier Reef in Australia. These places are so big that they are visible from space, making coral reefs the largest living structures on our planet.

These complex habitats only grow under specific conditions, requiring temperatures of 20 to 32°C and shallow, sunlit waters. These conditions vary naturally with our planet's cycles, but are altering more dramatically due to climate change. If sea temperatures rise, the zooxanthellae cannot survive, so they leave the polyps. The corals then lose their colour and most of their food, and the whole habitat is threatened. It's not just marine species that this will impact. Coral reefs are also an important resource for humans, providing food in many regions and they may also hold the key for the treatment of infections, heart disease and even cancer.

Key to plate

Belize Barrier Reef, Central America

1: **Reef manta ray**
Mobula alfredi
Width: Approx. 3.5m
This is the second largest species of ray in the world.

2: **Green turtle**
Chelonia mydas
Length: Approx. 1.5m
This turtle takes its name from the colour of its fat rather than the colour of its shell.

3: **Common bottlenose dolphin**
Tursiops truncatus
Length: Up to 4m
This species lives in social groups called pods. They can contain as many as 1,000 individuals.

4: **Staghorn coral**
Acropora cervicornis
Height: Up to 2m
This coral grows faster than most, adding 10–20cm a year.

5: **Blue chromis**
Chromis cyanea
Length: Up to 15cm
Normally found in big shoals, these bright fish live near branching coral when they are young and are always ready to dart for shelter if threatened.

6: **Table coral**
Acropora cytherea
Diameter: Up to 2m
Growing in flat, table-like structures, this coral gives prey animals shelter from predators hunting above.

7: **Brain coral**
Diploria labyrinthiformis
Diameter: Up to 2m
The brain coral's polyps sit protected within its maze-like grooves and folds.

8: **Spotted moray eel**
Gymnothorax moringa
Length: Approx. 60cm
This solitary eel lives in crevices in the reef. It normally hides away with only its head poking out.

9: **Caesar grunt**
Haemulon carbonarium
Length: Up to 20cm
Haemulon carbonarium
This family of fish, called grunts, make noises underwater by grinding their teeth together.

OCEANARIUM

Gallery 3

Molluscs and Echinoderms

Bivalves
Gastropods
Cephalopods
Echinoderms
Habitat: Deep Sea

Bivalves

With hinged shells made of two halves, bivalves are an interesting type of mollusc that are able to completely enclose themselves in an armoured cocoon, impenetrable to most predators. They are found in some shape or form throughout the ocean and can survive in some of the toughest habitats on Earth, including deep-sea hydrothermal vents which reach temperatures in excess of 300°C.

Because they are attached to the seabed (usually via a tough stringy material called byssal thread), bivalves don't move much after they have settled. This means that instead of hunting for food, they filter feed – using tiny hairs called cilia to catch passing plankton from the water. This method of feeding means bivalves also filter the water, making it cleaner for other animals and plants. Some species of bivalve provide a habitat for other creatures too – beds of mussels can support a variety of living things including seaweeds, worms, small fish and crabs.

Perhaps the most coveted feature of the bivalves is their ability to create nacre. This shimmering material is more commonly known as 'pearl', or 'mother of pearl', and is the only jewel on Earth created by an animal. Nacre is secreted as a form of defence – it smooths the inside of the bivalves' shells, protecting their soft bodies from harm and invasive parasites. If a parasite does make its way inside, layers of nacre are coated over, protecting the bivalve and, eventually, forming a pearl. Approximately only one in every 10,000 wild oysters will create a natural pearl.

Aside from use in jewellery, some bivalves have been cultivated for centuries for people to eat. The oyster is a good example of this, and there is evidence that this animal was grown for consumption in ancient Rome. Today, it remains a very popular seafood, and is harvested from the ocean by dredging or hand-picking.

Key to plate

1: **Common mussel**
Mytilus edulis
Length: Up to 10cm
These mussels usually grow in clumps, attaching themselves to rocks or each other by byssal threads.

2: **Queen scallop**
Aequipecten opercularis
Length: Approx. 7cm
As with all scallops, the Queen scallop can swim by opening and closing its shell, although this doesn't get it far.

3: **Flame shell**
Limaria hians
Length: Approx. 2.5cm
Named for its bright fringe of tentacles, this bivalve's shell is always slightly open, ready to catch food.

4: **Pacific oyster**
Magallana gigas
Length: Approx. 18cm
Originating from Japan, these animals are now farmed around the world.

5: **Common cockle**
Cerastoderma edule
Length: Up to 5cm
Cockle shells were used to make wavy patterns in prehistoric clay work known as Cardium pottery.

6: **Fan mussel**
Atrina fragilis
Length: Up to 48cm
This species is one of the rarest in the UK. It buries the narrow portion of its shell in the seabed, leaving the wider end out to feed.

7: **Giant clam**
Tridacna gigas
Length: Approx. 1.2m
Giant clams are the largest known species of bivalve and can live for around 100 years.

8: **Razor clam**
Ensis magnus
Length: Approx. 15cm
All razor clams dig into the sand, preferring to leave just their siphon out in the water to breathe. When burrowing, they can produce an impressive spout of water, which gives them the alternative name of 'spoots'.

Gastropods

More commonly known as slugs and snails, gastropods (meaning 'stomach foot') are molluscs. They are the only members of this group to successfully live on land, and in both saltwater and freshwater. Scientists estimate that there are around 65,000 species of marine gastropods, with the largest – the Australian trumpet snail – reaching nearly a metre long, and the smallest – the micro-molluscs – reaching only a few millimetres.

Typically, snails have coiled shells which protect them from predators. Made from calcium carbonate, a material found in rocks, these shells are strong and durable, and will often last long after the animal which made them has died. The discarded shells sometimes become homes for other animals, such as hermit crabs and worms, but will eventually break down into grains of sand to form beaches.

Sea slugs and the closely related sea hares have beautiful colours, patterns and sensory horns called rhinophores, which make them fascinating underwater creatures to observe. Though they lack a shell, they are by no means defenceless. Some, such as the blue dragon, can eat animals too dangerous for others to tackle – like jellyfish. In doing so, they steal the venom for their own defence. It is because of this that the striking colours found on sea slugs often serve as a stark warning to predators.

Gastropod diets vary between being herbivorous, carnivorous and omnivorous. Some are predatory, while others scavenge, and some are parasitic – feeding on the bodies of other living creatures. All gastropods eat using a tooth-like mouth called a radula, which is specially adapted to suit the eating habits of each species. Drill-shaped radulae make tiny holes in the shell of their victim, allowing the gastropod to squirt stomach acids inside, and, later, suck out the dissolved meal. Others are grazers and have radulae better suited to scraping algae from rocks.

Key to plate

1: **Blue dragon**
Glaucus atlanticus
Length: Up to 3cm
This slug hangs beneath the Portuguese man o' war, feeding on its stinging cells.

2: **Textile cone**
Conus textile
Length: Up to 10cm
Highly predatory and venomous, textile cone shells use their modified radula to fire deadly stings.

3: **Tiger cowrie**
Cypraea tigris
Length: Up to 15cm
Cowries can pull their soft bodies inside their shell when in danger.

4: **Sea hare**
Aplysia punctata
Length: Up to 7cm
The colour of these animals varies with their diet, which consists of red and green algae.

5: **Common limpet**
Patella vulgata
Diameter: Up to 6cm
The limpet's thick, conical shell offers a strong defence against predators and powerful waves.

6: **Anna's Chromodoris**
Chromodoris annae
Length: Up to 4cm
This colourful sea slug eats certain species of poisonous sponge.

7: **Alabaster Murex**
Siratus alabaster
Length: Up to 22cm
The spines covering this snail's exterior protect it from predators.

8: **Violet sea snail**
Janthina janthina
Length: Up to 4cm
Floating from a raft of self-made bubbles, this small snail hangs upside down at the water's surface.

9: **Queen conch**
Lobatus gigas
Length: Up to 35cm
The shells of this snail have been used as horn-like musical instruments by humans for over 10,000 years.

Cephalopods

Cephalopods are a group of highly intelligent invertebrates that include octopuses, cuttlefish and squid. From the tiny blue-ringed octopus to the mysterious giant squid, this remarkable group exhibit a huge range of lifestyles, habitats and complex behaviours.

The Greek translation of the word cephalopod is 'head-foot', which describes the way these creatures appear to have their heads attached to their many limbs. Cephalopods are soft-bodied animals, with strong muscles to control their multiple arms. Despite their jelly-like appearance, they do have a toughened beak in their mouths which is strong enough to pierce the shells of crabs and lobsters – their preferred prey. Many of these animals also possess a toxin which paralyses their victim, allowing them to be eaten safely. In some species, such as the blue-ringed octopus, this toxin is extremely potent – one bite from this tiny creature has enough venom to kill several humans.

Cephalopods have three hearts and blue, copper-based blood called haemocyanin. Their arms (with suckers) and tentacles (without suckers) are used to catch food and to move things around their habitat. These limbs are incredibly dexterous – the coconut octopus will even use its suckers to hold on to the insides of empty coconut shells while it encases itself safely inside.

Intelligence is a key feature of the cephalopod, too. Octopuses are particularly smart and research has proven that they are able to problem-solve and remember solutions. This means that they can be highly efficient escape artists, who, aided by their lack of bones, can squeeze their whole bodies through the tiniest of spaces to evade danger. Their skin also contains colour-changing pigment cells which allow them to camouflage with their environment. If none of these defences work, octopuses can produce a dark cloud of ink, which can act as a decoy and allow for a quick getaway.

Key to plate

1: **Hummingbird bobtail squid**
Euprymna berryi
Mantle length: Up to 5cm
This tiny squid has a symbiotic relationship with the glowing bacterium *V. fischeri*, helping it to camouflage.

2: **Dumbo octopus**
Grimpoteuthis bathynectes
Mantle length: Unknown
This is one of the deepest dwelling octopuses we know of, and it is incredibly rare.

3: **Flamboyant cuttlefish**
Metasepia pfefferi
Mantle length: Approx. 6cm
This cuttlefish doesn't swim as much as other species, but crawls along the ocean floor instead.

4: **Knobbed argonaut**
Argonauta nodosa
Length: Up to 3cm (males), 30cm (females)
These fragile looking animals are known as 'paper nautiluses' but are in fact octopuses. The females secrete a paper-thin shell to live in, and to hold their eggs while they grow.

5: **Giant Pacific octopus**
Enteroctopus dofleini
Mantle length: Up to 60cm
The largest known species of octopus, this giant can weigh around 60kg.

6: **Chambered nautilus**
Nautilus pompilius
Mantle length: Up to 20cm
These deep-sea creatures occupy the innermost chamber of their shell when first hatched and move into larger segments as they grow.

7: **Humboldt squid**
Dosidicus gigas
Mantle length: Approx. 1.5m
This species is also known as the red devil, due to its bioluminescent light.

8: **Greater blue-ringed octopus**
Hapalochlaena lunulata
Mantle length: Up to 4cm
The blue rings on this tiny octopus flash brightly when approached, warning of a deadly bite.

Echinoderms

Found in every part of the ocean, from the shallows to the deep sea, echinoderms either creep slowly over the seabed or are anchored in one place, gently sifting food out of the water as it passes by. In appearance, this group which includes starfish, sea cucumbers, sea urchins and sand dollars, can seem passive and defenceless, unable to chase prey or evade capture. However, these creatures are full of surprises. They are in fact amazing predators, capable of living in some of the most extreme environments on the planet.

With a name meaning 'spiny skin', echinoderms usually have a covering of tough spines which helps to protect them from predators. In addition to these spines, sucker-like protrusions also cover their undersides. Known as tube feet, these help echinoderms to stick to, or crawl along, the seabed and also grab hold of food. Tube feet can smell and taste the water around them, providing vital sensory information that can lead echinoderms towards food sources and away from predators.

By positioning themselves in places where they can catch ocean currents, echinoderms have many inventive ways of feeding. Sea cucumbers munch through the seabed, digesting any food they find and excreting clean sand in long coils behind them. Sea urchins use a different method. With five tough plates in their mouth, known as Aristotle's lantern, they scrape algae from rocks. Starfish are predators, preying on many creatures including sea snails, which they pull off rocks to get at the flesh inside. Unlike most other animals, starfish can take their stomachs out of their bodies, allowing them to digest food that does not fit in their mouths. This is important for an animal without teeth with which to chew a large meal.

Echinoderms have additionally inventive ways of defending themselves. Some crawl away, while others, like the sea cucumber, eject their digestive system, leaving it behind as a decoy. Incredibly, echinoderms can also regrow body parts lost to predators, and starfish can regenerate whole limbs. Just a single arm can regrow into a complete animal because it contains everything a starfish needs to survive.

Key to plate

1: **Crown-of-thorns starfish**
Acanthaster planci
Diameter: Up to 35cm
These spiny-looking starfish have up to 21 arms.

2: **Sea pig**
Scotoplanes globosa
Length: Up to 15cm
These sea cucumbers appear to walk along the ocean floor using long, tube-like limbs.

3: **Red slate pencil urchin**
Heterocentrotus mammillatus
Diameter: Up to 8cm
Thick, broad spines are characteristic of this group. The colour and thickness vary depending on their habitat.

4: **Crimson knobbed starfish**
Protoreaster linckii
Diameter: Up to 30cm
An impressive predator, this starfish eats clams, oysters and mussels as well as other starfish.

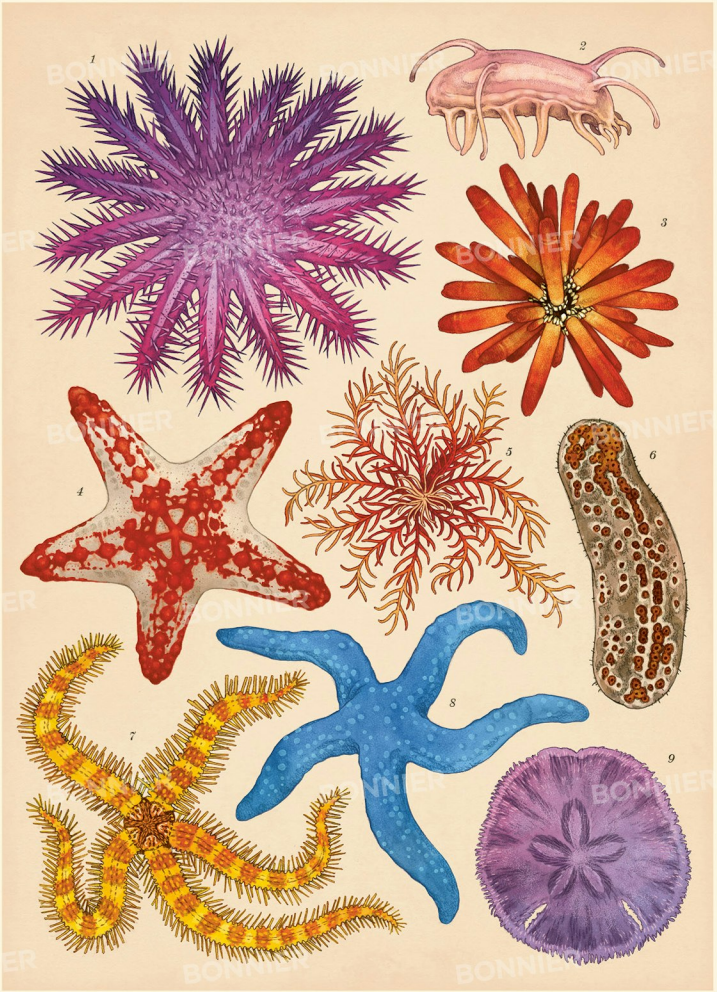
5: **Rosy feather star**
Anteadon bifida
Diameter: Up to 20cm
Feather stars are in a class called the crinoids. Their feather-like arms catch plankton from the passing water.

6: **Leopard sea cucumber**
Bohadschia argus
Length: Up to 60cm
This sea cucumber often has a small fish called a pearl fish living inside it.

7: **Spiny brittle star**
Ophiothrix spiculata
Diameter: Up to 12cm
These brittle stars tend to be small but occur in large numbers.

8: **Blue starfish**
Linckia laevigata
Diameter: Up to 30cm
A tiny parasitic snail is often found on the skin of this species.

9: **Eccentric sand dollar**
Dendraster excentricus
Diameter: Approx. 8cm
Sand dollars are flat, burrowing sea urchins. Their larvae can clone themselves, reducing their chances of being eaten by predators.



Habitat: Deep Sea

The deep sea is an alien, inhospitable place: it is constantly dark and cold, and the pressure is strong enough to crush most creatures. For a long time, people thought life could not survive here – but with the use of underwater vehicles, scientists have discovered life throughout the ocean's depths, and documented species whose features and behaviours enable them to survive in the most hostile conditions on Earth.

Because no light reaches the seafloor, no plants or algae can grow there so herbivores can't survive. The only way to feed is by scavenging, hunting or sieving tiny particles of food from the water. Most food drifts down from the surface, including fragments of algae, dead animals and other waste – it can take weeks to sink to the seabed. These soft, white flakes of 'marine snow' are vital for the diet of many deep-sea creatures. Occasionally, a real feast such as a whale carcass falls from the surface. Animals that may have gone for days without food will not let anything go to waste. Scavengers such as giant isopods, hagfish and sharks cover the carcass and eat all the meat in only a few months. What is left sinks into the seabed to be broken down by bacteria, leaving just the bones behind. Even these provide nutrients for tiny creatures that worm inside them to get to the fats and proteins.

Most of the time, however, animals must hunt for food, which can be a challenge in the dark waters. Many animals get around this problem by making their own light, a feature called bioluminescence. This is either made by chemicals inside their bodies, or via bacteria that live on them. Almost 90 per cent of creatures that live in open water are biolumescent, and most of these can be found in the deep sea, providing the only light visible in the inky depths. Though bioluminescence can allow predators to see in the dark, it more often attracts smaller fish towards hungry mouths. Other animals use light to communicate, flashing messages to each other through the gloom.

Key to plate

Abyssal plain, Atlantic Ocean

1: **Atolla jellyfish**
Atolla wyvillei
Bell diameter: Up to 17cm
When under attack, the atolla flashes blue. This attracts larger predators, which usually eat the original attacker – allowing the atolla to escape.

2: **Common northern comb jelly**
Bolinopsis infundibulum
Length: Up to 15cm
This predator hunts tiny zooplankton.

3: **Black dragonfish**
Idiacanthus atlanticus
Length: Approx. 40cm (females), 5cm (males)
This fish makes red bioluminescence. Most deep-sea animals can't see red, so the dragonfish can go unseen.

4: **Bluntnose sixgill shark**
Hexanchus griseus
Length: Approx. 3m
The sixgill is thought to resemble sharks from 200 million years ago.

5: **Humpback anglerfish**
Melanocetus johnsonii
Length: Approx. 18cm (females), 3cm (males)
The females of this species have a bright 'lure' to attract prey, and a huge mouth and stomach.

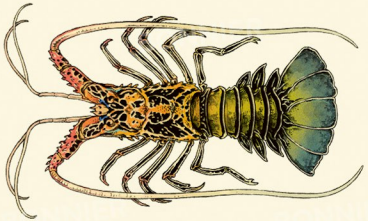
6: **Bone-eating snot flower worm**
Osedax mucofloris
Length: Up to 7cm
Female worms bore into whale fall bones to eat the marrow inside. Microscopic males live inside females.

7: **Atlantic hagfish**
Myxine glutinosa
Length: Up to 40cm
This carrion feeder can produce slimy mucus, clogging the gills of any attacker.

8: **Giant isopod**
Bathynomus giganteus
Length: Up to 36cm
This giant arthropod can go for weeks or even months without food.

Gallery 4

Arthropods



Crustaceans
Peacock Mantis Shrimp
Habitat: Rock Pool

Crustaceans

Crustaceans are members of a group called the arthropods, which include insects and arachnids. These are some of the most successful animals that have ever lived on our planet and, in fact, account for around 80 per cent of all known living species.

Identified by having bodies arranged into segments (the thorax, abdomen and head), crustaceans have different limb pairs associated with varying roles. Some are used for walking and swimming, others for catching and cutting food and some for sensing the environment. Crustaceans can also 'taste' with their feet and detect chemicals from other animals in the water. These senses allow crustaceans to find food as well as a good home, and are one of the reasons that this group of animals, from microscopic copepods to hefty lobsters, can thrive in every type of ocean.

A tough shell-like armour, or exoskeleton, covers the bodies of most crustaceans and protects them from predators. In order for them to grow, this exoskeleton must be shed often in a process that can take several weeks. Freshly moulted crustaceans are soft and vulnerable, and must hide or bury themselves until their new shell has hardened. Hermit crabs, however, have no exoskeleton on the rear half of their bodies, and so must find other means to protect themselves. Instead, they search the ocean floor, scavenging for discarded shells from other molluscs. Once sure that there are no other inhabitants, the hermit crab can move in and claim the shell for itself.

While most crustaceans can move around, barnacles adopt a more sedentary lifestyle. Firmly attached to the rocks, they can open tiny doors in their shell-like home, allowing them to feed on passing plankton. Before settling on a rock, larval barnacles will 'smell' the water – the odour of other barnacles will smell safe while that of a predatory dogwhelk will signal danger.

Key to plate

1: **Painted spiny lobster**
Panulirus versicolor
Length: Up to 30cm
These beautiful lobsters are nocturnal, and live alone in small caves and crevices in coral reefs.

2: **Acorn barnacle**
Semibalanus balanoides
Diameter: Up to 15mm
This barnacle spends its whole life cemented to a rock. It is covered with tiny hairs called cirri, which capture passing plankton.

3: **Norway lobster**
Nephrops norvegicus
Length: Up to 20cm
The tail of this small, slim lobster is known as scampi when it's eaten.

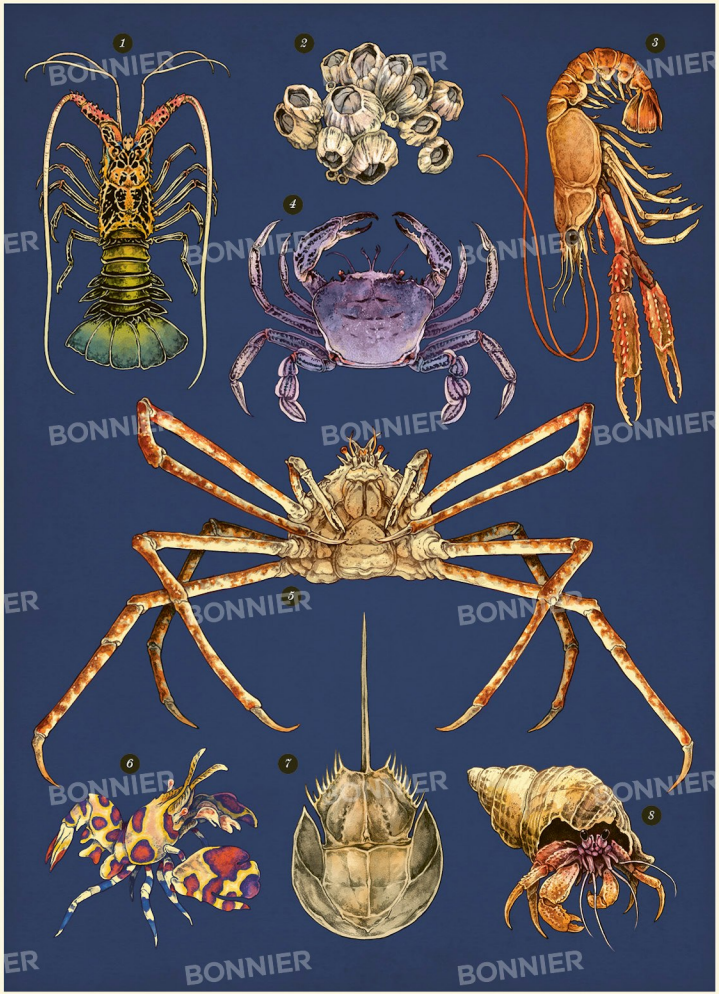
4: **Velvet swimming crab**
Necora puber
Carapace width: Up to 1m
These crabs are particularly feisty and have red eyes, earning them the alternative name of 'devil crab'.

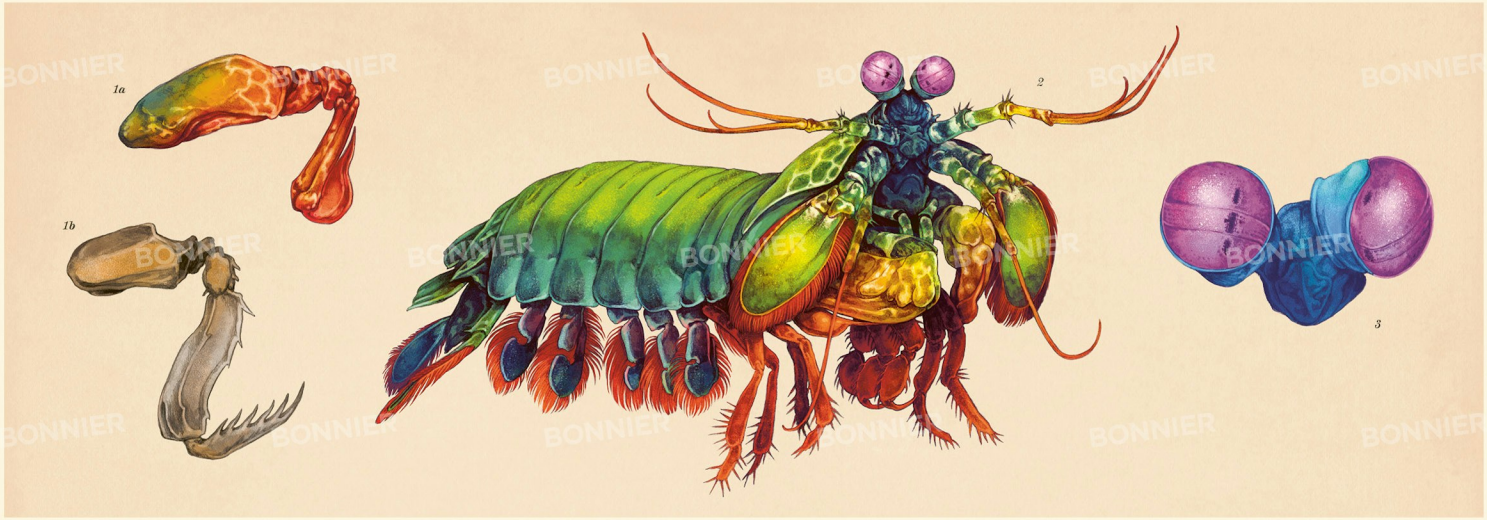
5: **Japanese spider crab**
Macrocheira kaempferi
Carapace width: 40cm
The largest known arthropod, the long legs of this crab can grow up to 4m. They often break, but can be regrown.

6: **Harlequin shrimp**
Hymenocera picta
Length: Up to 5cm
This species exclusively feeds on starfish, and will work together to flip them over, carry them back to their reef crevice and feed on them.

7: **Indo-Pacific horseshoe crab**
Tachypleus gigas
Length: Up to 50cm
The blood of this crab can release chemicals that clot blood when it becomes contaminated with a pathogen. For this reason it is often used in human vaccine and drug trials.

8: **Common hermit crab**
Pagurus bernhardus
Carapace length: Approx. 3.5cm
These crabs have no exoskeleton on the rear half of their bodies. They have been known to use plastic litter, such as bottle tops, as replacement shells.





ARTHROPODS

Peacock Mantis Shrimp

Despite their small size (typically less than 20 centimetres), peacock mantis shrimp are incredible hunters and fierce defenders of their territories. Burrowing under the sand, they lie and wait for unsuspecting prey, ambushing them with incredible force when they venture too close.

All mantis shrimp species have exceptionally powerful claws. Some use them to smash open shells, while others have spears, better for piercing softer meals, such as fish. With large, club-shaped claws, the peacock mantis shrimp is a 'smasher', repeatedly punching its shellfish prey to get at the meat inside. Scientists have estimated the speed of the 'punch' to be around 80 kilometres per hour – the same acceleration as a bullet. Each strike has two impacts: the first from the claw hitting the prey and the second from a phenomenon called cavitation bubbles – small gas-filled bubbles which release extra heat and light energy when they collapse, helping to kill their victim.

Mantis shrimps also have some of the most complex eyes in the world. Human eyes have three types of light-sensitive cells called photoreceptors which tell us what colour we are seeing. By comparison, mantis shrimp have between 12 and 16 of these types, which means they can see colours we can't imagine. They use this amazing eyesight to spot their prey but also to communicate. Specialised patches on their shells reflect light in a way that only other mantis shrimp can see, meaning that these feisty shrimp can send each other signals and warnings, avoiding unnecessary conflict.

Key to plate

***1a:* Claw (smasher)**
The claws of 'smasher' mantis shrimps, such as *Odontodactylus scyllarus* (pictured), have spring-loaded joints which store energy from the muscles, and they unleash it all in one go.

***1b:* Claw (spearer)**
The claws of 'spearer' mantis shrimps have deadly sharp barbs on the end of their thin claws. This helps them to jab and snag softer prey.

***2:* Peacock mantis shrimp**
Odontodactylus scyllarus
Length: Up to 18cm
There are over 400 species of mantis shrimp found throughout the world. This one is mainly found within the Indian and Pacific oceans, and is a bright and colourful inhabitant of shallow reefs.

***3:* Eyes**
Many light receptors facing in slightly different directions give the peacock mantis shrimp a large field of vision and the ability to see much faster movements than a human eye. The black band that runs down the centre shows which way the shrimp is looking.

Habitat: Rock Pool

Imagine the most changeable habitat you can, where nothing stays the same for long, including the temperature, the amount of oxygen you have to breathe, the space you can occupy and who you share the space with. This is life in the rock pools. Formed in the holes and rocky hollows of the shoreline, rock pools are shallow pockets of seawater left isolated from the sea at low tide.

Tides are the rise and fall of the planet's ocean. They are caused by the sun and moon's gravitational pull on Earth, making the ocean 'bulge' around its middle and pulling water away from the coasts. Because the moon orbits Earth, and Earth rotates on its axis, this pull works on different regions at different times, so that the tides change and move. Some places have faster tides than others because of their geography. For instance, the Bay of Fundy in Canada fills and empties a billion tonnes of water at around 15 kilometres per hour twice a day. That's much faster than most people can run!

For rock pool wildlife, it's important to be in the right place at the right time. Any creatures caught off guard by the tide risk finding themselves high and dry. To avoid this, animals carefully time their activities to fit around the tides' schedule and have a few handy 'backup' plans, too. Limpets leave a trail of mucus (slime) behind them when they search out food at high tide. As soon as the tide starts to retreat, they can follow the trail back to the safety of the rocks, where they clamp down, locking water inside their shell. Some animals, such as blennies, have adapted so that they can survive out of the water entirely. If they stay damp and cool, they can breathe through their skin, allowing them to wriggle and hop between rock pools – useful if there is no food in their rock pool or if they get caught out of the water.

Key to plate

Rock pool at low tide, United Kingdom

1: **Montagu's blenny**
Coryphoblennius galerita
Length: Up to 8.5cm
A single crest on the head makes this blenny identifiable from other species.

2: **Common limpet**
Patella vulgata
Diameter: 6cm
A limpets' radula is made of some of the toughest material known on Earth.

3: **Bladder wrack**
Fucus vesiculosus
Length: Up to 60cm
This seaweed has air bladders which allow the fronds to float in the water, where there is most sunlight. This helps them to stay close to the surface in order to photosynthesise.

4a: **Beadlet anemone (open)**
4b: **Beadlet anemone (closed)**
Actinia equina
Diameter: Up to 5cm
These territorial anemones will push others away that settle too close.

5: **Two-spotted goby**
Gobiusculus flavescens
Length: Up to 6cm
This species swims above the seaweed rather than sheltering under rocks.

6: **Common starfish**
Asterias rubens
Diameter: Up to 30cm
These starfish are experts at opening shellfish using their tube feet.

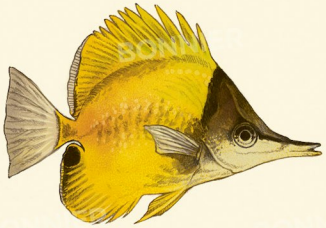
7: **Lightbulb sea squirt**
Clavelina lepadiformis
Height: Up to 2cm
Interestingly, these tube-shaped animals have a notochord (the beginnings of a spine) when they are larvae, but the adults remain invertebrates.

8: **Common periwinkle**
Littorina littorea
Height: Up to 5cm
This sea snail can often be found in clusters around rock pools at low tide.

9: **Shore crab**
Carcinus maenas
Carapace width: Up to 20cm
European natives, these common crabs have been introduced in South America, Australia and New Zealand.

Gallery 5

Fish



Coral Reef Fish
Seahorses and Pipefish
Rays and Skates
Sharks
Whale Shark
Habitat: Mangrove Forest

Coral Reef Fish

Coral reef fish inhabit one of the most diverse and beautiful ecosystems in the ocean – the coral reef. This is also one of the rarest habitats, requiring very specific conditions to grow and thrive (see page 22). The animals that call the reef home are there for a variety of reasons, but all of them rely on it in some way for their survival.

Coral reef fish are known for having beautiful patterns and bright colours, and are often flamboyant. These patterns and colours serve several purposes, from simply identifying members of the same species to helping the fish camouflage against the coral. Their appearance might also be used to attract a mate. Certain colours can also give a warning – reds and yellows often mean that an individual has venomous spines, poisonous skin or a sharp bite.

Finding food is a part of everyday life on the reef. With specially adapted mouths, surgeonfish and parrotfish graze on the algae that grows on the surface of coral. By removing the algae, which would otherwise smother the coral, these herbivores help to keep the reef alive. Corallivores, such as butterflyfish, consume the coral itself. By delicately picking off individual coral polyps, leaving most of the reef undamaged, these fish clear small patches on the reef where new coral can settle and grow.

Predators, such as sharks, also roam the reef, hunting for any small animals not hidden away. Small coral reef fish, like damselfish and anthias, benefit from a multitude of hiding places and safe spaces by living in this environment. The reef provides numerous caves and tunnels which are perfect for them to hide away from larger fish like groupers.

While some hide, other fish openly display their presence to even the largest and most predatory of creatures, all because they provide an important service. These so-called 'cleaner fish' remove unwanted dead scales and parasites from any fish visiting their 'station'. Cleaner fish receive food from the interaction, while larger animals are relieved of any itches caused by parasites.

Key to plate

1: **Longnose butterflyfish**
Forcipiger flavissimus
Length: Approx. 22cm
These territorial fish use their long snout to pick tiny invertebrates out from the reefs.

2: **Mandarinfish**
Synchiropus splendidus
Length: Up to 6cm
These beautiful fish don't have scales. Instead, they have a mucus coating, which protects them from bumps and scrapes as well as parasites.

3: **Powder blue surgeonfish**
Acanthurus leucosternon
Length: Up to 23cm
Surgeonfish get their name from the sharp spine on their caudal keel (the base of their tail).

4: **Coral hind**
Cephalopholis miniata
Length: Up to 50cm
These big fish draw food into their mouths by using a powerful suction, swallowing their prey whole.

5a: **Emperor angelfish juvenile**
5b: **Emperor angelfish adult**
Pomacanthus imperator
Length: Up to 40cm
This angelfish looks very different as a juvenile to its adult form. It is thought that this transition prevents the adults from seeing the juveniles as a threat to space and food.

6: **Clown anemonefish**
(seen inside anemone)
Amphiprion ocellaris
Length: Up to 11cm
These fish exist in a symbiosis with certain anemones found in coral reefs. Anemonefish gain protection from predators by living in the stinging tentacles of the anemone.

7a: **Bicolour parrotfish juvenile**
7b: **Bicolour parrotfish adult**
Cetoscarus bicolor
Length: Approx. 50cm
Parrotfish are all born female, with some transforming into males later in life. Like Emperor angelfish, their patterns change as they grow older.

8: **Bluestreak cleaner wrasse**
Labroides dimidiatus
Length: Approx. 10cm
These helpful fish inhabit specific sites on a coral reef and clean any fish that come to their station.

Seahorses and Pipefish

Despite their unusual appearance and misleading name, seahorses are in fact fish. They breathe via gills and contain a swim bladder among other fish-like features, but unusually they also have necks and bony plates covering their bodies and eyes.

In shallow habitats such as seagrass beds or coral reefs, seahorses use their curled, prehensile (gripping) tails to hold on tightly to their habitat. This is because they are poor swimmers and would otherwise drift away from safety with the strong ocean currents. All seahorses swim using small fins on their backs (dorsal fins) and steer with fins on the sides of their heads (pectoral fins). Even though their dorsal fin beats 30 to 70 times a second, most seahorses reach speeds of only a few metres an hour.

Although slow-paced, seahorses are remarkable hunters and are successful in catching their prey of copepods (a type of zooplankton – see page 12) 90 per cent of the time. By comparison, lions achieve a kill only around 20 per cent of the time. Seahorses are such successful predators because of the unique shape of their head. The streamlined shape barely disturbs the water around them, meaning they can sneak up on their prey unnoticed. When close enough, the seahorse will use rapid suction to catch its prey and disintegrate the food. This is important because seahorses have no teeth and so cannot chew – their food must be broken up quickly to digest.

Unlike most other animals, it is the male seahorse that gives birth. The female will make the eggs, then pass them to the male to hold in his brood pouch for incubation. The male will then look after the eggs until they hatch, expelling them in a cloud of tiny babies, known as fry, after 10 to 25 days. In the meantime, the female seahorse will have made more eggs, ready to repeat the process. Because of the synchronisation needed for seahorses to breed, a pair will stay together not for life but for at least a season, meeting every morning to hold tails and 'dance' to confirm their bond.

Key to plate

1: **Ornate ghost pipefish**
Solenostomus paradoxus
Length: Up to 12cm
Pipefish are related to seahorses and have a straightened body and tail. Unlike others in this group, the females of this species brood and give birth to their young.

2: **Long-snouted seahorse**
Hippocampus guttulatus
Length: Approx. 12cm
The spiny-looking protrusions on this seahorse give it a distinctive look.

3: **Leafy seadragon**
Phycodurus eques
Length: Up to 24cm
The amazing leaf-like structures on the body of this Australian seahorse are purely for camouflage. They make it difficult to distinguish the seahorse from leafy seaweed fronds.

4: **Big-belly seahorse**
Hippocampus abdominalis
Length: Up to 35cm
One of the biggest seahorses in the world, this species gets its name from its larger than usual 'belly'. The males have larger bellies because of their brood pouch.

5: **Bargibant's pygmy seahorse**
Hippocampus bargibanti
Length: Less than 2cm
These tiny seahorses are so well camouflaged in their coral habitat that they were only found when a piece of sea fan was examined in a lab by marine biologist Georges Bargibant in 1969.

Rays and Skates

With an evolutionary history stretching back over 250 million years, there have been five cataclysmic events on Earth resulting in the mass extinction of many animals – including the dinosaurs – since cartilaginous fish first appeared. This lucky group managed to evade this fate by retreating to the depths of the ocean and continue on today.

Gracefully gliding through the water or resting undetected on the seafloor, rays and their cousins, skates, are a group of animals with a skeleton made of cartilage (tough, flexible tissue). Most adopt a bottom-dwelling lifestyle, feeding on shrimp and crabs, while others, like the giant manta ray, are filter feeders, 'flying' through the water using winglike appendages – scooping plankton into their mouths as they go.

Millions of years of evolution mean both rays and skates have adapted highly effective ways of staying safe. From spots and speckles to marbled tones, both have sophisticated markings and patterns on their skin, making them almost undetectable against the sand below or sunlit waters above. Rays and skates often look similar and it can be difficult to spot the difference. The sting, or lack of one, is a differentiating feature to look for – rays have stings on their tails, while skates have a thicker tail, often with small fins. Rays use their stings to defend themselves, although they typically prefer to stay still and camouflage to avoid danger. Skates have thorny spines on their backs and will usually cover themselves in sand to evade detection.

Reproduction is an interesting feature in rays and skates, and there are a variety of ways they breed. Skates encase their developing young in a tough case known as a 'mermaids' purse', which is lain on the seabed. The fetus will develop inside these capsules for up to a year, emerging when ready. The mermaid purses are disguised to look like pieces of seaweed and will eventually be covered by a film of algae, helping them to stay hidden. By comparison, rays give birth to their young fully formed, at which point they swim away to start their lives independent from their parents.

Key to plate

1: **Spotted eagle ray**
Aetobatus narinari
Width: Up to 3m
Extending up to 5m, much of the length of this big species is made up by its long, thin tail, which it uses to sense movement behind it.

2: **Bowmouth guitarfish**
Rhina ancylostoma
Length: Up to 3m
The unmistakable body shape of this fish is between that of a shark and ray, hence its other common name of 'shark ray'.

3: **Giant oceanic manta ray**
Mobula birostris
Width: Approx. 4.5m
These are the largest known rays in the world, reaching up to 7m in width.

4: **Marbled electric ray**
Torpedo marmorata
Length: Up to 60cm
This ray uses its electrical charge defensively and can deliver 70–80 volts of electricity in one hit – the same voltage as an electric lawnmower.

5: **Knifetooth sawfish**
Anoxypristis cuspidata
Length: Approx. 3.5m
Sawfish all have a long, tooth-edged nose (rostrum), which has pores for detecting electrical fields. The sawfish can use this to detect hidden prey, who give off electrical impulses.

6: **Bluespotted ribbontail ray**
Taeniura lymma
Width: Approx. 35cm
The bright blue spots on this beautiful ray are attractive but warn of a dangerous sting.

7: **Undulate ray**
Raja undulata
Length: Up to 1m
Despite its name, this is a species of skate. It gets its name from the undulating motion it creates with its wings while swimming.

Sharks

These prehistoric animals have roamed the ocean for around 450 million years, and today there are over 500 species of shark. Much maligned and often feared by humans, the truth is that only a handful of species are responsible for bites, and attacks are incredibly rare. These fascinating animals have evolved to be hugely varied in size, shape and lifestyle, and it is because of these many adaptations that they have maintained their position as the ocean's top predator.

With an enormous habitat to hunt in, sharks must use their senses to track a meal down over huge distances. Along with their incredible sense of smell, sight, touch, taste and hearing, these highly sensitive creatures have an extra sense that allows them to detect the electricity produced by the muscles of living things. They can sense this via tiny, jelly-filled pores that are dotted around the head, particularly on the underside of the snout. Named after the Italian scientist who discovered them, these pores, known as Ampullae of Lorenzini, are able to detect very low charges in water – great white sharks can detect one millionth of a volt.

Efficiency is important when travelling such vast distances too. To save energy, sharks have special streamlining scales known as dermal denticles. These scales are shaped more like teeth and all point the same way – from nose to tail. This arrangement helps to reduce drag and turbulence which lets the sharks cut through water easily, allowing for faster and quieter swimming. Sharks also have a super-light cartilage skeleton, which provides extra speed. The only bony part of a shark is their teeth, which have evolved to be unique to each species and perfectly suited to their prey. They form in multiple rows in a shark's mouth and will constantly re-grow throughout their lives.

As well as being impressive and beautiful creatures, sharks are of incredible importance to the health of our ocean, too. Sharks tend to hunt for animals that are sick and therefore easier to catch. Without sharks, disease can spread more easily.

Key to plate

1: **Epaulette shark**
Hemiscyllium ocellatum
Length: Up to 90cm
These small sharks will often use their pectoral and pelvic fins to walk on the seabed, rather than swim.

2: **Great white shark**
Carcharodon carcharias
Length: Up to 5m
This revered animal can keep its blood temperature up to 25°C higher than the surrounding water.

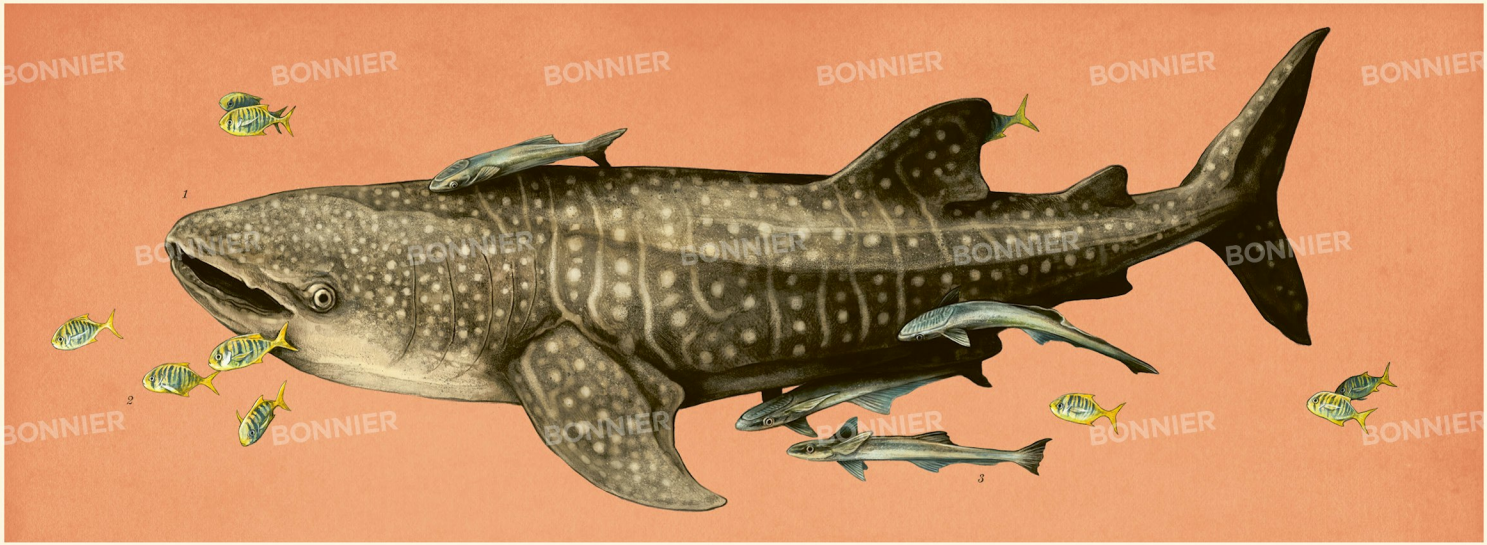
3: **Common thresher shark**
Alopias vulpinus
Length: Up to 5m
The extra-long upper lobe of the caudal fin (tail) is used to stun fish.

4: **Cookiecutter shark**
Isistius brasiliensis
Length: Up to 56cm
This small shark is parasitic, attaching itself to larger animals to bite off chunks of flesh. The deep bitemarks are perfectly rounded, giving this shark its name.

5: **Basking shark**
Cetorhinus maximus
Length: Up to 8m
Second only in size to the whale shark, these enormous fish are in fact plankton eaters.

6: **Tasselled wobbegong**
Eucrossorhinus dasypogon
Length: Up to 2m
This incredible camouflaged shark has a fringe of dermal lobes that make it look like coral or algae to an unsuspecting fish. This, along with their complex patterns, makes them masters of disguise.

7: **Oceanic whitetip shark**
Carcharhinus longimanus
Length: Approx. 3m
These sharks are named for their large, rounded fins that have white tips to them.



Whale Shark

Whale sharks are ocean-roaming giants, migrating huge distances to reach the richest feeding grounds. They only eat microscopic plankton as well as tiny fish and eggs, filtering them from the water with their massive mouths. Reaching lengths of around 10 metres, whale sharks are the largest fish in the world, yet certain aspects of their lives still remain a mystery to us.

Large groups of whale sharks are seen seasonally in the waters off the Yucatan Peninsula in Mexico. They are thought to gather here to eat the millions of eggs produced by spawning tuna. Regular sightings mean the area has become a hotspot for wildlife tourism as well as shark research. One female tagged here was documented completing a migration of around 7,000 kilometres, covering about 50 kilometres a day. It is possible that she was travelling to give birth to her young, maybe out in the open ocean.

Nobody has ever seen a whale shark give birth, so we can only guess where this takes place. Scientists think females may go to remote islands like the Galápagos and give birth deep underwater. From a specimen caught in 1996, we know that whale sharks give birth to live pups that hatch from eggs inside their mother, which is known as ovoviviparous reproduction. In this specimen, there were 300 pups measuring 40–60 centimetres long, relatively small considering the gargantuan size of the adults.

Instead of electronic tagging, more and more researchers are relying on a different method to identify whale sharks and record their movements. This technique is based on the unique pattern of spots found across the sides and backs of all whale sharks – a pattern as unique as human fingerprints. Using this arrangement, scientists can identify individuals from photographs, and see how far a single shark has travelled without having to tag it. This used to be a long, slow process, until an algorithm used to identify star constellations was adapted to work on whale shark spots. Now, computer software can help with the identification of individual whale sharks, helping us to learn more about the lives of these incredible animals.

Key to plate

1: **Whale shark**
Rhincodon typus
Length: Up to 18m
This huge animal is named for its large size and for its filter-feeding behaviour, which it has in common with baleen whales. Whale sharks live in open, tropical waters around the world. Although nobody can be sure, they are thought to grow up to 18m long and to live for as long as 70 to 100 years, reaching sexual maturity at around 30 years old.

2: **Golden trevally pilotfish**
Gnathanodon speciosus
Length: Up to 1.2m
These brightly coloured pilot fish are often found alongside whale sharks. They are attracted by the leftover food the whale shark leaves behind when it is feeding.

3: **Remora**
Remora remora
Length: Approx. 40cm
Remora fish suction on to larger animals such as whale sharks and use them to 'hitch' a lift over long distances. The whale shark is not affected positively or negatively by this.

Habitat: Mangrove Forest

Mangrove trees can survive conditions that would kill most other plants. Growing in tropical coastal areas, these resilient plants can withstand salty water, intense sunshine, changing tides and crashing waves. This is thanks to a number of unique adaptations: prop roots branch from the trunk and strengthen trees so they can withstand storms; porous upright roots take in oxygen from the air, topping up low oxygen levels in the silty water; and leaves can filter out as much as 90 per cent of the salt from the water their roots absorb.

Where roots enter the water, they create caves and tunnels – the perfect hiding places for fish and other small animals. This is especially useful for young animals, including lemon shark pups, which may use the mangrove as a nursery before starting their adult lives in other habitats. Other creatures live in the mangroves for their whole lives or will come and go seasonally. Specialised animals, such as the mudskipper, even take advantage of the living space above the water, hopping and sliding on the mud to catch a meal of insects.

Because mangrove trees grow along coastlines, they offer excellent natural protection from the erosive force of the sea. Without mangroves, coastal communities would experience more frequent damage from storms that blow in from the ocean. Mangrove forests are also incredibly important for the role they play in sheltering young fish. These juveniles later go on to support food chains across the ocean, providing food for thousands of different animals – including humans.

Key to plate

Mangrove forest, South East Asia

1: **Fiddler crab**
Uca annulipes
Carapace width: Up to 2cm
Males have one small claw and one large one, which they wave in the air to attract a female.

2: **Mangrove plant**
Rhizophora racemosa
Height: Approx. 30m
Rhizophora seeds can survive floating in water for days or weeks until they reach a good site for growth.

3: **Barred mudskipper**
Periophthalmus argentilineatus
Length: Up to 19cm
Mudskippers can survive out of the water when the mangrove's tides drop each day.

4: **Hardyhead silverside**
Atherinomorus lacunosus
Length: Up to 12cm
Shoals of these little fish can contain several hundred individuals.

5: **Indo-Pacific tarpon**
Megalops cyprinoides
Length: Up to 45.5cm
The tarpon uses its swim bladder to breathe air, taking in more oxygen and allowing for greater speed.

6: **Sicklefin lemon shark**
Negaprion acutidens
Length: Up to 3.8m
When these sharks are pups, they shelter and hunt in the mangrove.

7: **Silver moony**
Monodactylus argenteus
Length: Approx. 12cm
Stripes make it hard for other animals to tell which way the moony is facing.

8: ***Rhizophora racemosa* seed**
Length: Up to 30 cm
When ready, these seeds drop into the water and are carried away by currents. Once in a suitable location, they settle and grow.

OCEANARIUM

Gallery 6

Mammals

Cetaceans
Blue Whale
Pinnipeds
Manatees and Dugongs
Habitat: Kelp Forest

Cetaceans

Found throughout the ocean from the tropics to the freezing poles, cetaceans are a group of marine mammals that include whales, dolphins and porpoises. All members of this enigmatic group share special adaptations that allow them to swim enormous distances and stay warm.

Cetaceans have many of the same features as land mammals – they are warm-blooded, breathe air with their lungs and care for their young, feeding them highly nutritious milk. Like their mammal cousins on land, this group also have some hair, mostly in the form of sensory whiskers around the mouth. Yet despite their similarities, cetaceans have very different ways of feeding. The odontocetes – toothed whales – have small, sharp teeth suited to hunting and killing large prey, while the mysticetes – baleen whales – use brush-like baleen to filter tiny plankton from the water. As air-breathers, cetaceans also need to hold their breath to hunt for prey. Sperm whales undertake dives to depths of around 2,250 metres and can hold their breath for up to 90 minutes.

Cetaceans often feed and breed in different parts of the ocean, meaning they must travel between the two areas every year. As strong, powerful swimmers, they are well-equipped for these voyages, and all cetaceans have a thick layer of fatty blubber for insulation. These migratory journeys can cover huge distances, with some species repeating yearly migrations of nearly 5,000 kilometres. Incredibly, humpback whales are known to complete a 16,400 kilometre round trip, travelling between the Equator and the Antarctic.

These long-distance ocean migrants need to communicate with other whales, dolphins and porpoises to survive, and they do this in sophisticated and surprising ways. Baleen whales use deep-sounding songs which travel huge distances, while dolphins communicate via clicks and whistles. Regional groups of whales and dolphins can even have dialects and individual sounds for each other, a bit like human voices.

Key to plate

1: **Short-beaked common dolphin**
Delphinus delphis
Length: Up to 2.4m
Found in groups of hundreds, if not thousands, of individuals, these animals are very social and spend all of their time together.

2: **Commerson's dolphin**
Cephalorhynchus commersonii
Length: Up to 1.5m
These small dolphins are playful and agile swimmers, often swimming upside down or leaping into the air.

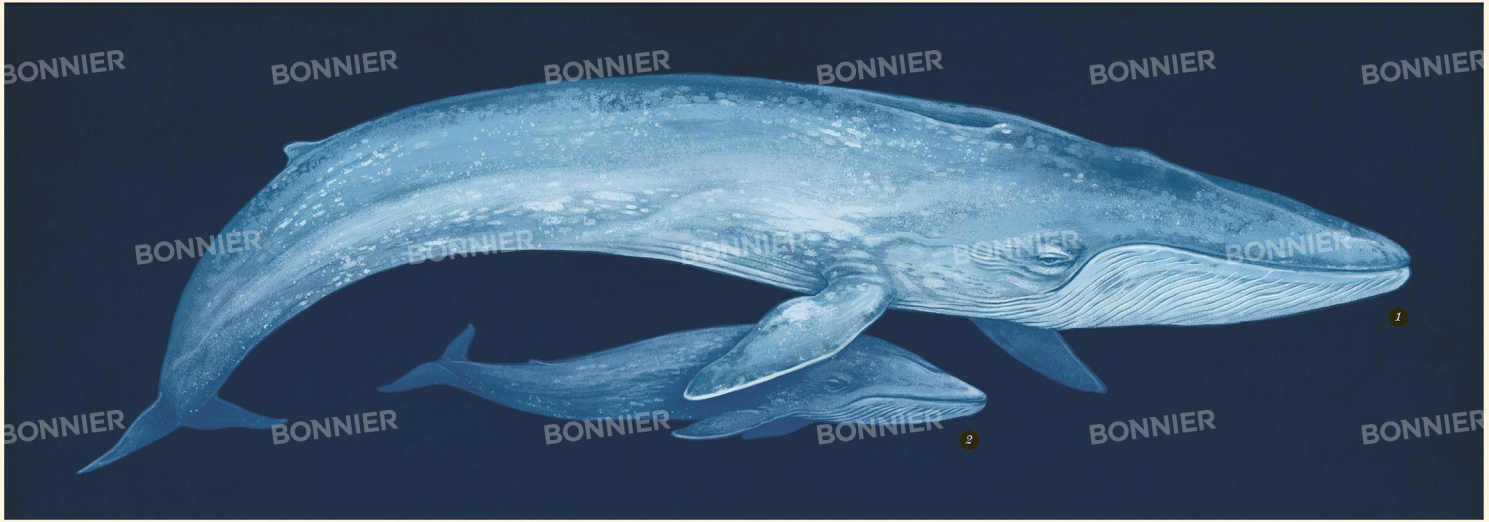
3: **Sperm whale**
Physeter macrocephalus
Length: Up to 18m
This deep-sea diver is known to prey on giant squid.

4: **Harbour porpoise**
Phocoena phocoena
Length: Up to 2m
Porpoises are very similar in appearance to dolphins but have a shorter beak with flatter, spade-shaped teeth.

5: **Humpback whale**
Megaptera novaeangliae
Length: Up to 16m
Despite their name, these whales do not have a hump on their back, but they form a distinctive curved shape when diving underwater.

6: **Common minke whale**
Balaenoptera acutorostrata
Length: Approx. 10.2m
One of the smallest baleen whales, this species is often preyed upon by orcas (see page 74).

7: **Beluga whale**
Delphinapterus leucas
Length: Up to 5m
Like all polar whales, the beluga has no dorsal fin. This means it can swim beneath the ice without scraping itself.



Blue Whale

The blue whale is the largest animal that has ever lived on our planet, reaching lengths of up to 30 metres. Weighing nearly 200 tonnes, blue whales can have a heart the size of a small car. Their enormous size rivals that of the largest dinosaurs and is only possible because they live in water – a supportive environment that stops their weight from crushing their organs. These leviathans have been cruising our ocean for nearly 1.5 million years, but during the twentieth century the blue whale population dropped by over 99 per cent. This was due to the practice of whaling, whereby whales were hunted for their meat, oil and bones. Faced with extinction, blue whales were protected in 1966 and have slowly started to recover, but despite this their population today is still at a fraction of the pre-whaling numbers.

In addition to being the largest, blue whales are also one of the loudest animals in the world. Males are the most vocal and can reach 188 decibels – louder than a jet engine. Although their songs can be detected by other blue whales up to hundreds of kilometres away, they cannot be heard by humans because their low-pitched frequency is too deep for us to hear.

Interestingly, the largest animal on Earth survives by eating one of the smallest. Shoals of tiny krill are sieved from the ocean by these giants using baleen – plates of hair-like fibres that hang in their mouths. Blue whales can eat around four tonnes of krill in a single day with an enormous mouth that expands via pleats in their throats. In a feeding lunge, blue whales engulf not only thousands of individual krill but also tonnes of water. Their huge baleen plates catch and sieve out the food before being swallowed down a relatively small throat.

Blue whales migrate between cold and warm waters to feed and to breed, spending the warmer months feeding at the poles, and the cooler months nearer the Equator where they meet to breed. Females have babies every two to three years and are pregnant for around a year before giving birth to a seven-metre-long calf.

Key to plate

1: **Blue whale**
Balaenoptera musculus
Length: Up to 30m
Blue whales need to be able to find large quantities of food from reliable sources. As they migrate from their breeding to feeding grounds, they must remember where their prey is and find their way back there. Scientists think that blue whales memorise this, and time their migrations to best fit the time when there is the most krill to eat.

2: **Calf**
Length: Approx. 7m at birth
A baby will feed on about 200 litres of its mother's rich, fatty milk, gaining weight at a rate of 100kg a day. It will stop feeding when it is six months old, by which time it will be around 16m long.

Pinnipeds

The pinnipeds are a group that includes some of the fastest and most agile marine mammals, most of which survive in the coldest waters on Earth. These sleek predators are most at home swimming underwater, but they also make use of land or ice floes as a refuge from predators. There are three sub-groups within the pinnipeds: seals, sea lions and walruses.

True seals are identifiable by their lack of visible ears. Perfectly adapted for life in glacial water, seals have large eyes that work well in the dark, and a thick coat of blubber and fur that keeps them warm and further streamlines their bodies. Seals usually breed on solid ground or on ice floes around the Arctic or Antarctic, but are not well-adapted for life on land as they can't use their back flippers out of the water. Instead, they must use their strong stomach muscles and short front flippers to pull themselves forwards.

Sea lions and the closely related fur seals do have visible ear flaps on the sides of their heads. They are agile, graceful swimmers and can twist and turn in the water much more easily than seals. They often spend time out of the water and can rotate their long muscular flippers forwards so that they can walk on land.

The third group of pinnipeds has only one species: the walrus. Formidable in appearance, these hefty creatures spend a lot of their lives in water, hunting for clams and other invertebrates. Once they find a meal, walruses use their lips to clamp over it and pull their tongue backwards, causing so much suction that the animal is pulled from its shell. Other than its size, the main defining feature of the walrus is their enormous tusks which both males and females possess. These nearly one-metre-long teeth are used by males to display dominance and win the right to breed with females, but they are also used to keep ice holes open in the winter – vital for any air-breathing mammal living on the ice.

Key to plate

1: **Ribbon seal with pup**
Histriophoca fasciata
Length: Up to 1.6m
The striking patterns of the ribbon seal develop as they grow. They are born white and later moult, looking like their parents at around 4 years old.

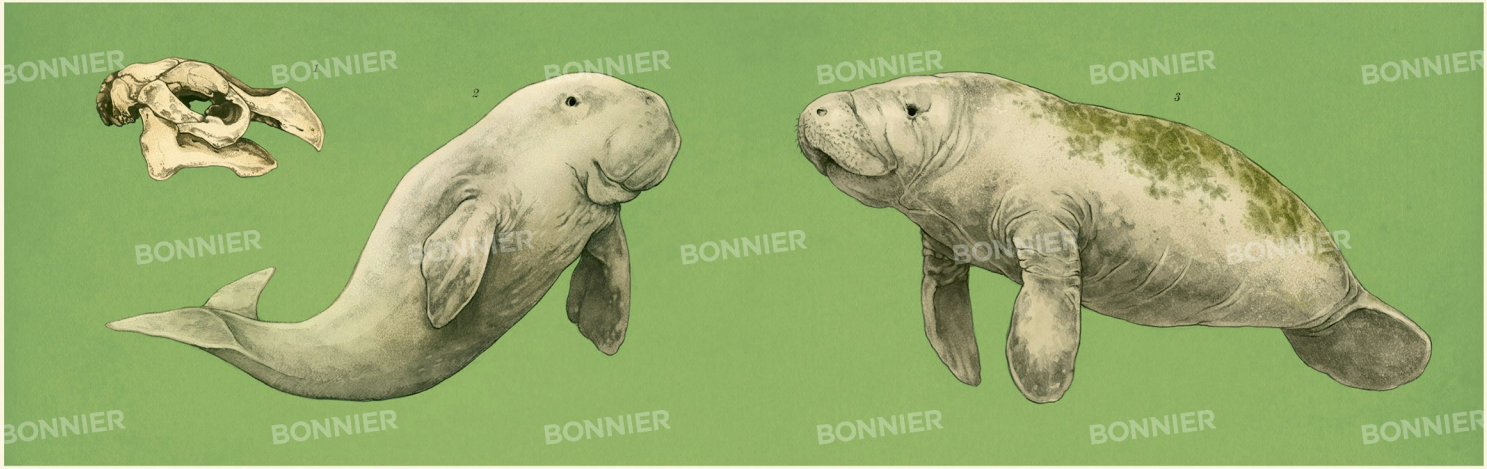
2: **Antarctic fur seal**
Arctocephalus gazella
Length: Up to 1.8m
The fur of these creatures was so popular as clothing in the eighteenth and nineteenth century, they were hunted almost to extinction.

3: **Californian sea lion**
Zalophus californianus
Length: Up to 2.4m
Like all pinnipeds, sea lions have vibrissae (whiskers) around their faces, which help them to detect the movements of prey in the water.

4: **Walrus**
Odobenus rosmarus
Length: 2.2–3.6m
Weighing over 1,500kg, these adults may eat as many as 6,000 clams in one feeding season.

5: **Harbour seal**
Phoca vitulina
Length: Up to 1.9m
Harbour seals live in the northern hemisphere, where they feed on crustaceans, molluscs and fish.

6: **Southern elephant seal**
Mirounga leonine
Length: 2.6–5.8m
One of the deepest diving mammals, this species has been recorded at depths of 2,000m. The males have protruding noses which they use to attract females.



Manatees and Dugongs

Gracefully swimming in shallow waters, these marine mammals were once mistaken for mythical creatures by sailors. They have since inspired many tales of mermaids, and the order sirenia – to which manatees and dugongs belong – in fact derives its name from the Greek word for 'siren'.

Today, manatees and dugongs are more commonly known as sea cows. With large bodies, a slow lifestyle and the need to graze for hours at a time, they do have similarities with their land-based namesake, and are the only herbivorous marine mammals still alive today. Their cousins, the Steller's sea cows, were sadly hunted to extinction and unfortunately, both manatees and dugongs are today classified as vulnerable. Although both mammals are aquatic, they still need to breathe air, and resurface every five minutes or so to take a breath.

Occupying the tropical waters around the north coast of Australia, India, Indonesia and eastern Africa, dugongs use their strong, flexible upper lip to pull up seagrass – of which they must consume up to 50 kilograms a day. This activity leaves furrows behind in the seabed, and often disturbs small invertebrates, making an easy meal for golden trevally fish that often trail alongside them.

The three species of manatee are found in different locations: the Caribbean, West Africa and the Amazon basin. Unlike dugongs, manatees can travel into rivers from the sea, and the Amazonian manatee lives exclusively in freshwater. With a lack of insulating blubber, manatees must stay in water with temperatures between 15 and 20°C. This means they migrate in the colder months, sometimes finding warm springs in freshwater where many individuals will huddle together for warmth.

Despite having few natural predators, numbers of manatees and dugongs are in decline. Affected by toxic algae blooms (see page 10) and the loss of warm marine habitats, these animals are additionally vulnerable to watercraft accidents and many are killed or seriously injured in this way every year.

Key to plate

1: **Steller's sea cow skull**
Hydrodamalis gigas
Length of skull: Approx. 61cm
Hunted to extinction by 1768, all that remains today of the Steller's sea cow are fossils such as this. They reached enormous sizes, growing up to 10m long and weighing as much as 11 tonnes – larger than many modern-day whales.

2: **Dugong**
Dugong dugon
Length: Up to 3m
Dugongs are slightly smaller than manatees, and have fluked tails similar to dolphins. This is the only species of dugong alive today.

3: **West Indian Manatee**
Trichechus manatus
Length: Up to 3.5m
Manatees are distinguishable from dugongs via their large, rounded paddle tail, and nails on their flippers. The largest member of this group today, this species of manatee is increasing in numbers thanks to conservation efforts.

Habitat: Kelp Forest

Kelp is a kind of seaweed that grows in cool coastal regions. Unlike plants on land, seaweeds have a gripping holdfast instead of roots, which attaches to the rocky seabed, anchoring against storms and ocean currents. Each holdfast has one or more stipes (stalks) reaching up to the surface. Air-filled floats called pneumatocysts stop the stipes from sinking, and ensure the kelp is close enough to the sunlit surface to photosynthesise. Some types of kelp grow as tall as 45 metres, forming vast forests that tower above the seabed. Just like a rainforest on land, this ecosystem has several layers where animals can shelter and find food: otters snooze in the canopy; sharks stalk prey in the kelp's corridors; and invertebrates shuffle slowly across the seafloor.

As in all ecosystems, there is a delicate balance between photosynthesising organisms (such as seaweed), herbivores and carnivores. In the kelp forest, this balance is best seen in the relationship between kelp, sea urchins and sea otters. Sea urchins graze on the kelp, making space for new plant growth. Sea otters then feed on the urchins, which stops them becoming too plentiful and eating all the kelp. However, sea otter hunting in the eighteenth and nineteenth centuries meant there weren't enough otters to keep the urchins in balance. The sea urchins boomed, feasting on the kelp, and in places it died back completely, creating areas known as urchin barrens. Kelp forests are susceptible to other changes too. Frequent storms can rip the kelp from its holdfast; warming seas bring less of the nutrients needed for kelp growth; and poor water quality reduces the light levels needed for photosynthesis. It is possible that, as our ocean warms due to climate change, kelp forests may move further north to cooler waters.

Key to plate

Kelp forest, Californian coast, United States of America

1: **Southern sea otter**
Enhydra lutris nereis
Length: Up to 1.4m
Sea otters were hunted extensively for their fur in the 1700s and 1800s. Conservation efforts are helping their numbers to recover.

2: **Bull kelp**
Nereocystis luetkeana
Length: Approx. 36m
Bull kelp extracts are used in a range of everyday items, including ice-cream.

3: **Garibaldi fish**
Hypsypops rubicundus
Length: Approx. 30cm
Territorial males defend a nest site year-round. In the spring, a male will clean the nest site and entice females in with swimming performances.

4: **Leopard shark**
Triakis semifasciata
Length: Approx. 1.6m
Young sharks are experts at finding snails and crabs under the sandy seabed and often frequent kelp forests.

5: **Giant kelp**
Macrocystis pyrifera
Length: Approx. 45m
Giant kelp can grow as much as 45cm a day, making it one of the fastest-growing organisms on Earth. When detached from the seabed, it floats in mats, giving shelter to many animals.

6: **California sheephead**
Semicossyphus pulcher
Length: Approx. 91cm
This species starts out as a female and turns into a male later in life.

7: **Purple sea urchin**
Strongylocentrotus purpuratus
Length: Approx. 10cm
These voracious invertebrates pose a threat to kelp forests – 90% of the bull kelp forests in California, USA, have been devoured by them.

8: **Rockfish**
Sebastes sp.
Length: 12–104cm, depending on species
One of the longest-lived fish – some rockfish can live for around 100 years.

Gallery 7

Birds

Seabirds
Habitat: The Poles

Seabirds

Seabirds make up around 3.5 per cent of all bird species. Whether they spend the majority of their lives gliding over the waves like the wandering albatross or visit the ocean only to collect food like the puffin, these birds all have a connection to the sea. Their plumage is often less colourful than other birds, which helps them camouflage against the ocean waves.

The hunting methods of seabirds vary with each species. Some, like the blue-footed booby, will plummet almost 30 metres from the air into the sea, diving underwater in pursuit of prey. Others are better adapted to surface feeding, either skimming the water while still in flight or, in the case of the Wilson's storm petrel, stopping for a moment to dip their feet in the water, to attract plankton to the water's surface. Penguins have given up flight altogether and have strong, short wings that behave more like flippers, providing powerful swimming strokes underwater.

Many seabirds migrate to breed, with some travelling enormous distances. Wandering albatross have been known to fly around 10,000 kilometres in a single journey, barely flapping their wings. Instead, they use the wind, catching updrafts to keep themselves airborne and to conserve energy. Each season, they gather on rocky outcrops at sea or on cliffs. Males and females pair together, with some returning to each other after long periods apart. This bonding between parents means that they can successfully care for their chick while one adult is away foraging for food.

This strategy is important for emperor penguins too – the only animal that spends the winter in Antarctica. These amazing birds will walk 80 to 120 kilometres inland to breed in colonies. Once the egg is laid and hatched, the pair will take turns to guard their chick, while the other returns to feed at sea. Only by working together can they raise the next generation of emperor penguins in such extreme conditions.

Key to plate

1: **Herring gull**
Larus argentatus
Wingspan: Up to 1.5m
Climate change may have turned this bird from a predator into a scavenger – taking food from waste and even directly from people.

2: **Wilson's storm petrel**
Oceanites oceanicus
Wingspan: Up to 42cm
At home in stormy seas, these birds fly through the troughs of the waves, avoiding the worst of the weather.

3: **Red-billed tropicbird**
Phaethon aethereus
Wingspan: Up to 1.1m
A favourite food for this bird is flying fish, which they are known to catch in mid-air.

4: **Wandering albatross**
Diomedea exulans
Wingspan: Up to 3.5m
Wandering albatrosses have the largest wingspan of any bird and can spend years at sea without returning to land once.

5: **Blue-footed booby**
Sula nebouxii
Wingspan: Up to 90cm
The bright blue feet on these birds are used by the males to attract a mate as part of a display of courtship.

6: **Atlantic puffin**
Fratercula arctica
Wingspan: Up to 63cm
When the breeding season is finished, these birds shed their colourful beak plates and eye patches.

7: **Australian pelican**
Pelecanus conspicillatus
Wingspan: Up to 2.6m
This species has the longest beak of any known bird, reaching up to half a metre.

8: **Emperor penguin**
Aptenodytes forsteri
Height: Up to 1.2m
This is the largest penguin species. They can dive to depths of up to 500m in search of food.

9: **African penguin**
Spheniscus demersus
Height: Up to 70cm
The only penguin to be found on the continent of Africa, this penguin has to cope with hotter environments. The pink patch above their eye helps them to lose heat.

Habitat: The Poles

Some of the most extreme environments on Earth are found at the North and South poles. Almost inhospitable, with temperatures as low as -80°C, winds that reach 100 miles an hour and darkness for half the year, these ice-covered regions of the world are home to only the toughest creatures.

Antarctica is found at the southernmost tip of our planet and is a continent that is covered in and surrounded by ice. The Arctic is an area of ocean at the northernmost reaches of Earth, and forms part of several countries, including Finland, Norway, Iceland, Greenland, Russia and the United States. It is a diverse region, with some areas experiencing seasonal melts and some covered permanently in ice up to three metres thick. The soil on land, known as tundra, is permanently frozen and supports only low-growing plants with shallow roots.

First impressions might suggest that it would be difficult for life to thrive here, yet the Arctic is home to many animals, from mystical-looking narwhals to majestic polar bears and a host of migratory seabirds and sealife. One of the reasons that such a diverse range of wildlife can be found here is because the cold waters are nutrient-rich, providing the perfect conditions for phytoplankton to bloom. These important microscopic creatures are the very first link in the food chain, which includes top predators like polar bears and orcas.

As the seasons change and temperatures vary, the fluctuating levels of ice can influence the life cycles of the wildlife. Humpback whales, for example, swim from their breeding grounds to the Arctic or Antarctic during the summer to access water usually trapped under ice during the winter. But scientific evidence shows that sea ice is melting unnaturally fast due to climate change, damaging the habits of these creatures.

The ice in our polar regions also has a wider effect on our planet too. Known as the albedo effect, the bright white ice reflects light and heat back into space, keeping us cool and the climate constant. Without polar ice, more of the sun's heat will become trapped and our planet will get much hotter. It is vital that we monitor and reduce our impact on these vulnerable parts of the world, or we could be faced with an ice-free Arctic in the near future.

Key to plate

An Arctic ice shelf, Arctic Ocean

1: **Arctic tern**
Sterna paradisaea
Wingspan: Up to 75cm
These birds migrate incredible distances, flying between the Arctic and Antarctic, to catch the summer season in both. They travel around 35,000km each year.

2: **Polar bear**
Ursus maritimus
Length: Up to 3m
The biggest bear in the world and the largest land carnivore, the polar bear spends most of its time on the Arctic sea ice. It is also a strong swimmer.

3: **Narwhal**
Monodon monoceros
Length: Up to 5.5m
Male narwhals have spiral-shaped horns which can reach up to 3m.

4: **Arctic cod**
Arctogadus glacialis
Length: Approx. 32.5cm
Amazingly, Arctic cod have a kind of antifreeze in their blood. This stops them from freezing in the icy waters around the poles.

5: **Orca**
Orcinus orca
Length: Up to 8m
These apex predators can communicate to hunt together and are one of the most intelligent cetaceans known (see page 60).

Gallery 8

Reptiles

Turtles
Saltwater Crocodile
Sea Snakes
Habitat: Galápagos Islands

Turtles

Sea turtles are ancient creatures that have lived in the ocean for around 200 million years, making them one of the oldest reptiles alive today. With their thick protective shells, streamlined bodies and powerful webbed flippers, they are well-adapted for life at sea. Often completing journeys of thousands of miles across entire oceans, they are strong swimmers with an amazing ability to navigate through featureless expanses of open water.

Sea turtles have varied diets which differ between species. Loggerhead turtles are omnivorous, eating a range of crustaceans, molluscs and coral, as well as algae. Other turtles are more selective. The leatherback, for example, has a diet that consists mainly of jellyfish. Green turtles change their diet as they grow, with omnivorous juveniles becoming mostly herbivorous adults. The algae and seagrass consumed by the adult green turtles turns their flesh a green colour, which gives this species its name.

When not sleeping, eating or mating, turtles migrate between feeding and breeding areas. Leatherback turtles have been known to travel 16,000 kilometres in search of jellyfish to eat, while some loggerhead turtles swim nearly 13,000 kilometres from Japan to Mexico to feed, then return to Japan to breed – a round trip of 26,000 kilometres.

In a similar way to humans using satellite navigation, turtles use the planet's magnetic field to find the beach on which they were hatched, returning every season to lay their own eggs. This incredible journey is followed by the enormous physical challenge of dragging their heavy bodies out of the water; digging a large hole and laying their eggs – of which there can be up to 100 in a single nest. When their job is done, the females return to the sea, leaving the eggs to incubate beneath the sand. Young turtles are a great source of nutrition, and many predators eagerly await for them to hatch. As a defence mechanism, the babies will all emerge at the same time, racing down the beach toward the sea. Once in the ocean, they will spend their whole life in the water, with females only leaving to lay their own eggs, returning to the beach once more.

Key to plate

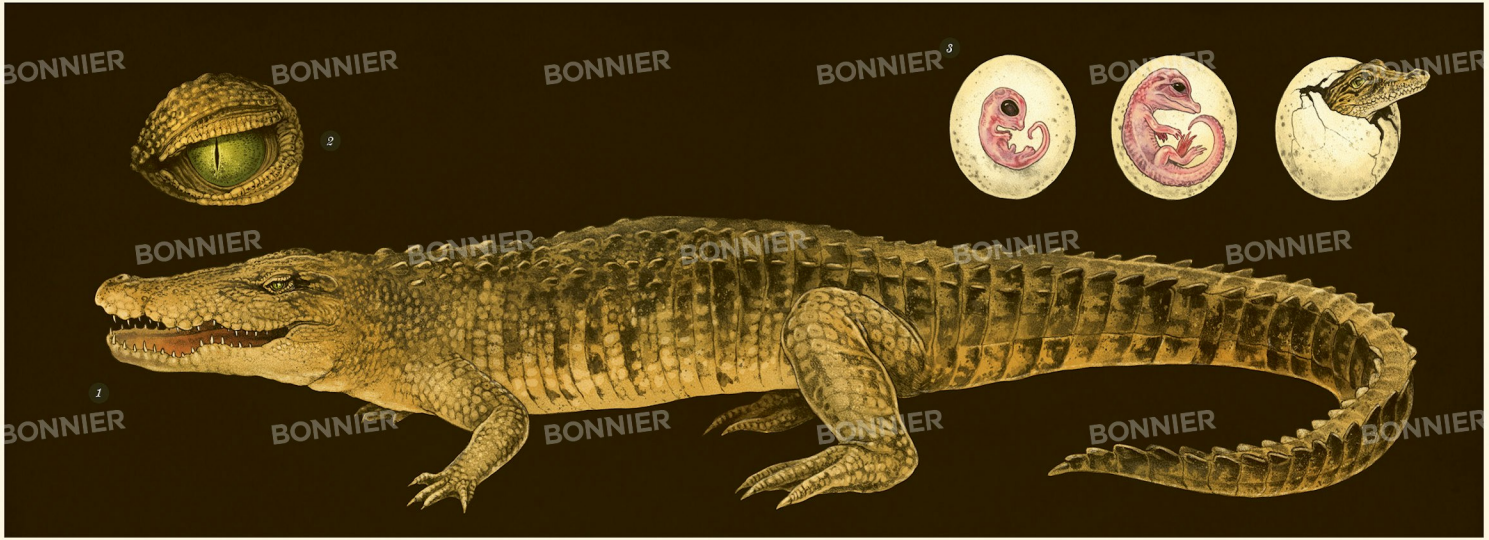
1: **Loggerhead turtle**
Caretta caretta
Shell length: Approx. 1.2m
Named for its large head and strong jaws, these turtles are able to crush clam shells and crunch sea urchins.

2: **Hawksbill turtle**
Eretmochelys imbricata
Shell length: Up to 90cm
This species' shell is unique in that its shell sections (scutes) overlap, creating a beautiful, distinctive pattern.

3: **Leatherback turtle**
Dermochelys coriacea
Shell length: Up to 2.2m
Weighing around 500kg leatherback turtles are the largest living sea turtles. Unlike other turtles, they can swim in colder waters.

4: **Olive ridley turtle**
Lepidochelys olivacea
Shell length: Up to 60cm
The most abundant of all the species, this small turtle nests in huge numbers in an event called an 'arribada'.

5: **Green turtle**
Chelonia mydas
Shell length: Approx. 1.1m
Of all the sea turtle species, green turtles are the only herbivores as adults. They are also the only sea turtles to leave the water for purposes other than egg laying – they will sunbathe on beaches to keep warm.



Saltwater Crocodile

Saltwater crocodiles are the biggest living reptiles in the world and have a lineage that stretches back to the time of the dinosaurs. With massive, powerful bodies, including a formidable set of jaws and a long muscular tail, these creatures are capable of ambushing large prey such as zebras, buffalo and even sharks. They are often found in estuaries where the river meets the sea.

With a jaw strength more powerful than any other animal on Earth, these enormous predators lurk beneath the surface, barely visible to unsuspecting prey coming to drink at the water's edge. They attack their prey with spectacular speed and agility, holding on tightly with their jaws and dragging the animals underwater. At this point, the crocodile will roll, causing its victim to drown. This technique is known as the 'death roll'. But their eating habits are not always violent. Saltwalter crocodiles are unfussy eaters, and they will also eat a variety of smaller creatures from the shallow waters and shores where they live, including crabs, snails and fish.

Despite their fearsome reputation, female saltwater crocodiles are attentive and caring parents. Mothers lay their eggs in piles of mud and vegetation and continually guard and tend to them. The gender of the babies is decided by the temperature at which they develop – lower temperatures produce females and higher temperatures produce males. After an incubation period of a few months, the hatchlings will call to their mother who will dig them out of the nest, gently carrying them in her mouth to the water where she will care for them for several months.

Key to plate

1: **Saltwater crocodile**
Crocodylus porosus
Length: Up to 3.5m (females) /5.2m (males)
Because these impressive reptiles rely on freshwater and land to live and breed, they aren't thought of as marine reptiles, and often only travel through the ocean to get to a new island. Scientists think they use ocean currents to 'surf', instead of paddling with their webbed feet.

2: **Close up of eye**
Crocodiles have sharp focus spread horizontally across their field of vision. This means that they can search for prey on the shore without moving their heads. Their eyes and nostrils are located on the top of their heads so they can almost fully submerge while still being able to keep a lookout.

3: **Embryo in development**
Female saltwater crocodiles lay around 50 eggs. After two to three months, the babies are ready to hatch. Young crocodiles will form a toothed area on their snout called an 'egg tooth', which they use to help break open the shell.

Sea Snakes

All snakes can swim, but sea snakes are so well-adapted to life underwater that most never leave their ocean home. Born in the water, sea snakes will spend their whole lives swimming, diving beneath the surface to hunt for prey and returning to the surface to breathe air. Evolving from land snakes, only one group of sea snakes (sea kraits) still move on to solid ground to have their young, but most species have lost the rough scales on their undersides, which means they cannot grip dry terrain. A true sea snake is not able to glide like a land snake.

To help them to swim, sea snakes have flattened, paddle-like tails, small heads and thin bodies which enable them to cut through the water. Because sea snakes are cold-blooded reptiles and need to get their heat from the environment, they must stay in warm water. This means they are limited to tropical parts of the ocean, with many staying close to the coast. Other sea snakes are pelagic (living in the open ocean) and use ocean currents to help them move around.

Freshwater can be hard to come by in the ocean, but sea snakes need to drink. Some will wait for it to rain, at which time there will briefly be a layer of freshwater on the surface of the sea. Any salt they accidentally ingest will be secreted from around their tongue and spat back into the water. It is this behaviour, as well as their need for warmer water, that has kept them from spreading into the Atlantic – any routes into this ocean, such as around the Cape of Good Hope in South Africa, are too cold and have very little rain.

Sea snakes have a very potent venom which is delivered through a bite and can be used either defensively or to catch their prey of fish and small octopuses. This venom is a neurotoxin, meaning that it causes muscles in the victim to stop working (paralysis) so the snake can eat without risking harm to itself. It is very rare for people to be bitten by sea snakes and fatalities are almost unheard of.

Key to plate

1: **Turtle-headed sea snake**
Emydocephalus annulatus
Length: Up to 90cm
The venom of this snake is quite weak, and it will often retreat rather than try to bite in defence. It feeds only on eggs laid by fish.

2: **Yellow-bellied sea snake**
Hydrophis platurus
Length: Up to 88cm
This snake is entirely pelagic, diving under the water to hunt. They can breathe through their skin which helps them to stay underwater for longer.

3: **Yellow-lipped sea krait**
Laticauda colubrina
Length: Up to 1.5m
Sea kraits such as this one are semiaquatic. They spend time on land to lay their eggs and to digest food, and only go to sea to hunt for their prey. Because of this, sea kraits are often found along coasts.

4: **Golden sea snake**
Aipysurus laevis
Length: Up to 2m
Like all snakes, the golden sea snake has to shed its skin, or moult, periodically. It does this by using the coral reef to snag the edges of its skin, peeling it off slowly. Moulting helps snakes to grow and rids them of parasites that attach themselves to their skin.

5: **Belcher's sea snake**
Hydrophis belcheri
Length: Up to 1m
This sea snake is highly venomous but is docile and rarely attacks humans. If it does, it doesn't always inject toxin and its short teeth often won't pierce through a diving wetsuit.

Habitat: Galápagos Islands

The Galápagos Islands are located on the Equator, 1,000 kilometres west of Ecuador. Rising from the depths of the Pacific Ocean 3,000 metres below the surface, this archipelago of islands was formed by ancient volcanic activity, and there are still active volcanoes on some of the islands today.

Although they are located where the climate is usually hot, the Galápagos generally experience cool, drizzly weather. This is because of the Humboldt Current – an 800-kilometre-wide strip of cold, nutrient-rich water that passes the Galápagos, not only cooling the air above it, but also providing the nutrients needed for phytoplankton to bloom, triggering hundreds of different food chains.

Both above and below the water, the islands are home to a range of unique species, many of which occur nowhere else on Earth. This is known as endemism, and is a common feature of island ecosystems, where the distance from the mainland means species evolve in isolation. One of the most famous examples of an endemic species from the Galápagos is that of the marine iguana – the only iguana in the world to swim in the sea. These reptiles graze on algae growing on rocks under the water, returning to land to bask in the sun and warm themselves. They were documented by Charles Darwin during his travels on board the *HMS Beagle* in 1835 (he described them as "most disgusting, clumsy lizards") and were among the creatures that inspired him to develop his theory of evolution and write *On the Origin of Species*.

Around 3,000 marine species live and feed in the Galápagos region. As a result of this impressive number – and of the region's many endemic species – the islands are now a marine protected area (MPA) covering around 130,000 square kilometres. By limiting fishing and protecting wildlife, the MPA aims to protect the unique nature of this incredible corner of the world.

Key to plate

Galápagos coastline, Republic of Ecuador

1: **Magnificent frigatebird**
Fregata magnificens
Wingspan: Up to 2.4m
These huge birds are known to peck at other seabirds to make them regurgitate their food so they can steal it for themselves.

2: **Galápagos penguin**
Spheniscus mendiculus
Length: Approx. 49cm
This small penguin can live in this tropical location only because of the cool waters of the Humboldt Current.

3: **Marine iguana**
Amblyrhynchus cristatus
Length: Up to 1m
The only marine lizards in the world, these iguanas have blunt snouts so they can scrape algae off underwater rocks.

4: **Flightless cormorant**
Phalacrocorax harrisi
Length: Up to 1m
These birds evolved without any predators, so with no need to fly they gradually lost the ability to do so. Humans later introduced cats and dogs to the islands, making the cormorants vulnerable to predation.

5: **Sally Lightfoot crab**
Grapsus grapsus
Carapace width: Up to 8cm
These beautiful crabs live on the rocks just above the water and are very agile.

6: **Bullseye pufferfish**
Sphoeroides annulatus
Length: Approx. 18cm
The name 'bullseye' comes from the circular markings on this fish's back.

7: **Scalloped hammerhead**
Sphyrna lewini
Length: Up to 2.5m
The iconic head of this shark gives it a wider field of vision.

8: **King angelfish**
Holacanthus passer
Length: Approx. 15cm
Males and females will pair for a whole breeding season, meeting to spawn every day.

Gallery 9

One Ocean

Habitat: Open Ocean
Humans and the Ocean

Habitat: Open Ocean

Move away from the coast and you will eventually reach the open ocean: a vast expanse of water where there is no land in sight. The animals found here have adapted to survive the challenges of an environment where food is scarce, and the distances are enormous.

The open ocean, also known as the pelagic zone, extends from the sea's surface to just above the seabed. Below 200 metres there is little or no sunlight, so most creatures congregate in the upper waters, where sunlight enables phytoplankton to photosynthesise. Just like plants on land, phytoplankton need nutrients. In the ocean, these come from the land, carried by rivers and streams to the sea. In large parts of the open ocean these nutrients don't reach the surface, but where they do, they feed enormous blooms of phytoplankton, providing food for a huge variety of ocean creatures.

Smaller creatures often make up for their size by forming shoals. This group behaviour provides protection from predators through safety in numbers – in a larger group, predators are faced with a mass of moving fish, making it difficult to pick out any one. But when predators target a shoal, it can become a bait ball: the fish swim closer together, shifting and changing direction in a split second to respond to the movements of the hunters. Bait balls can attract a number of larger predators, each with their own approach to capturing a meal. Dolphins work together to push the ball of fish towards the surface, taking it in turns to dash in. Tuna and sharks rely on their speed, power and agility to outswim individual fish, while bulk feeders such as whales lunge through the middle of the shoal, consuming hundreds of fish in one go. Once this feeding frenzy has finished, the predators continue on their way, often leaving little more than scales drifting down into the deep.

The story of the open ocean doesn't end there, as ocean predators are not the only hunters in this realm. Humans often frequent these waters to catch many species of fish to feed people back on land, putting a strain on the sea's dwindling resources. We must recognise that there is one ocean which supports all life on our planet.

Key to plate

Open waters, Pacific Ocean

1: **Blue flying fish**
Exocoetus volitans
Length: Approx. 20cm
Flying fish use their wing-like fins to glide above the water's surface. They can usually 'fly' around 50m, but on an updraft can travel up to 400m!

2: **Mahi-mahi**
Coryphaena hippurus
Length: Approx. 1m
Females lay between 100,000 and one million eggs in one go, two to three times a year, meaning mahi-mahi are plentiful.

3: **Silky shark**
Carcharhinus falciformis
Length: Approx. 2.5m
These sleek hunters are one of the most common open ocean sharks, found in warmer waters worldwide.

4: **Pacific herring**
Clupea pallasii
Length: Approx. 25cm
This small fish is vital to numerous ocean food chains. Herring fishing also supports many communities along the Pacific coast of America.

5: **Indo-Pacific sailfish**
Istiophorus platypterus
Length: Approx. 2.7m
Widely thought to be the fastest fish in the world, this species has been recorded at speeds of up to 110km/h.

6: **Yellowfin tuna**
Thunnus albacares
Length: Approx. 1.5m
Yellowfin tuna swim in large schools, often with other animals, such as dolphins or other species of tuna.

7: **Pacific white-sided dolphin**
Lagenorhynchus obliquidens
Length: Approx. 2m
White-sided dolphins often travel in 'super pods' of up to 100 individuals.

Humans and the Ocean

The ocean is one of humanity's greatest assets. Eight-thousand-year-old archaeological evidence showing the remains of primitive dugout canoes suggest that humans have had a centuries-old relationship with the ocean. Over the years, we began to understand more about the potential benefits of this resource, its contribution to food, travel, medicine, tourism – and more recently – as a source of renewable energy. Due to its immense size, it was once thought that the ocean was inexhaustible, but we now know this is not the case.

With a growing population, our dependence on the ocean has never been greater. Our sometimes excessive consumption of resources has led to environmental issues that impact humanity as well as wildlife around the world. Increasing demand for seafood as well as rising pollutants such as plastics, oil and greenhouse gases have led to parts of the ocean being unable to support the life they once did. But this can change.

The ocean is resilient and can recover if given time. Scientific studies have shown that the environment can improve and damage can be reversed, if protective measures are put in place. Marine scientists and engineers have more knowledge and technology at their disposal than ever before, which have led to initiatives such as wind farms (providing sources of green energy); the rise of protected marine habitats (ensuring the survival of endangered species); more sustainable ways of fishing; and improved ways of living that can reduce our global carbon footprint. More people than ever before are aware of the problems facing our planet and are seeking out ways to help. Whether it is by making small changes to our everyday lives or by campaigning and spreading the message – together, people can make a difference and can write a positive future.

Key to plate

1: **Offshore wind farm**
Wind farms help to produce clean renewable energy. The UK currently has more offshore wind farms than any other country, and in 2020 they generated 10% of the UK's total energy supply.

2: **Agricultural runoff**
Pesticides used in crops can wash into rivers and flow into oceans, causing harm to many marine animals, also triggering harmful algal blooms (see page 10).

3: **Large fishing boat**
Large ships can spend weeks at sea, catching thousands of tonnes of fish.

4: **Fish farms**
Sustainable fish farms take care not to damage the local environment or use harmful chemicals. They provide well-kept, healthy food for people without taking animals from the wild.

5: **Ecotourism**
Ecotourism encourages support for local communities and marine habitats as well as promoting conservation and preservation.

6: **Marine Protected Area (MPA)**
Only around 4% of the world's ocean is protected, but studies have proven these areas are effective in allowing fish populations to recover. In the Philippines, for example, numbers of surgeonfish and jackfish have tripled.

7: **Coral bleaching**
Coral reefs lose their colour when the ocean's temperature rises or its chemical composition is altered (see page 22).

Library

Index

Curators

Loveday Trinick is a marine biologist working as a Schools Officer for the Ocean Conservation Trust. Based within the National Marine Aquarium in Plymouth, she teaches school children of all ages about the ocean and why it is important to all of us. Loveday enjoys seeing children inspired by animals and creating connections to the marine environment – she believes this is the best way to help conserve our ocean for future generations.

Teagan White is an artist and illustrator living in the Pacific Northwest. They use depictions of flora and fauna to celebrate the intricate beauty of the natural world and illustrate the fraught relationship between humans and the rest of nature. They are currently a member of the University of Washington's Coastal Observation and Seabird Survey Team (COASST) and Oregon Shores' CoastWatch – two citizen science projects dedicated to monitoring ecosystem health and public land use, by collecting baseline data to help assess patterns of seabird mortality due to natural and human-induced events.

To Learn More

National Marine Aquarium
The UK's largest aquarium has developed a learning programme in conjunction with the Ocean Conservation Trust and national curriculum guidelines.
https://www.national-aquarium.co.uk

The Ocean Conservation Trust
Beautifully presented and with a whole host of projects to take part in, this website runs initiatives that encourage people to think about the ocean via positive experiences and connections.
https://oceanconservationtrust.org

Marine Conservation Society
Full of great initiatives for working towards a more sustainable and environmentally friendly planet.
https://www.mcsuk.org

Ocean Animal Encyclopedia
Discover each ocean creature in more detail in the fully comprehensive Ocean Animal Encyclopedia.
https://oceana.org/marine-life

National Geographic
Test your knowledge with National Geographic's ocean quizzes and learn more through interactive facts.
https://www.nationalgeographic.com

Sea Trust
Part of Wildlife Trusts, this non-profit organisation regularly update their website with wildlife sightings from around the UK.
https://seatrust.org.uk

National Oceanic and Atmospheric Administration
The NOAA have an extensive range of resources, perfect for students who want to explore more about climate change, marine life, pollution and much more.
https://www.noaa.gov

Census of Marine Life
This website is the result of a global, decade-long initiative by over 2,700 scientists. Fully comprehensive, the database catalogues over 30 million records, which feature updates on new species, marine conservation, habitat monitoring and new discoveries.
http://www.coml.org/index.html