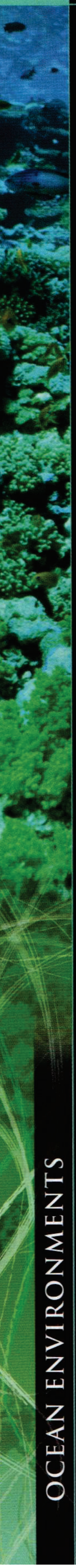


ZONES OF THE OPEN OCEAN

CONDITIONS IN THE OCEAN vary greatly with depth. Light and temperature changes occur quickly, while pressure increases incrementally. Although many of these changes are continuous, the ocean can be divided into a series of distinct depth zones, each of which produces very different conditions for living things.

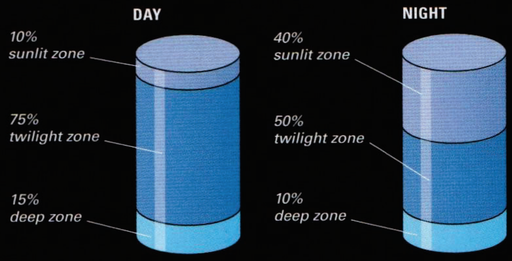
THE SURFACE LAYER

The top three feet of the ocean is the richest in nutrients. This upper layer is sometimes called the neuston, although this term is also used for the animals that live there, such as jellyfish. Amino acids, fatty acids, and proteins excreted by plants and animals float up into this surface layer, as do oils from the decomposing bodies of dead animals. These produce a rich supply of nutrients for phytoplankton.

The top three feet of seawater is also the interface where gas exchange takes place between the ocean and the atmosphere. This is vitally important to all life on Earth, as half of the oxygen animals need for survival comes from the ocean. Not surprisingly, phytoplankton gathers in this surface zone in daylight, as do the animals that feed on them. This zone is also highly susceptible to chemical pollution and floating litter, which can be deadly for marine life.

NOCTURNAL AND DIURNAL DISTRIBUTION

Only a small proportion of marine life inhabits the deep zone; the majority live above 3,300 ft (1,000 m). The sunlit zone is dangerous for animals—many stay in the twilight zone by day and only go upward at night. The sunlit zone is much emptier by day.



HUMAN IMPACT

FREE DIVING

When divers breathe compressed air underwater, excess nitrogen dissolves in their blood, and they risk the bends if they surface too fast. Free divers avoid this by holding their breath underwater. Pressure squeezes their lungs, but the surrounding blood vessels swell to protect them, and blood nitrogen levels stay safe. Trained free divers can hold their breath long enough to reach 660 ft (200 m), using aids to help them descend and ascend.

OCEAN ZONES

SUNLIT ZONE 0–660 ft
Seawater rapidly absorbs sunlight, so only one percent of light reaches 660 ft (200 m) below the surface. Phytoplankton use the light to photosynthesize, forming the base of food chains. This zone drives all ocean life.

TWILIGHT ZONE 660–3,300 ft
Too dark for photosynthesis, but with just enough light to hunt by, many animals move from this zone into the sunlit zone at night.

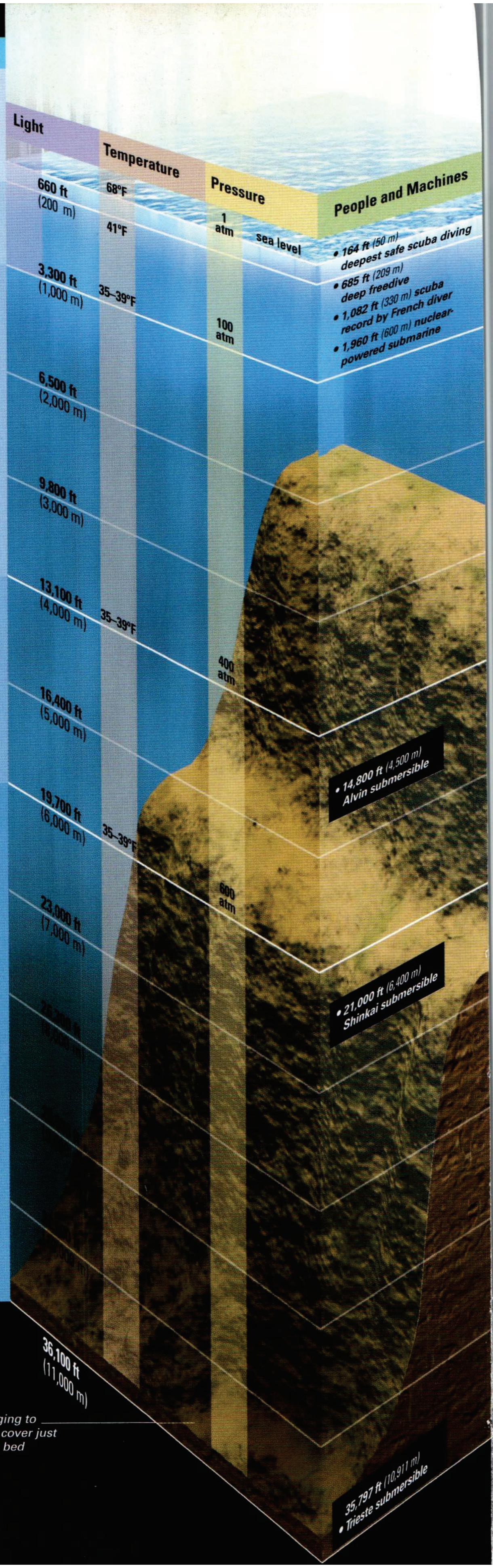
DARK ZONE 3,300 ft–13,100 ft
Almost no light penetrates below 3,300 ft (1,000 m). From here to the greatest depths, it is dark, so no plants can grow, and virtually the only source of food is the "snow" of waste from above. Temperatures down here are a universally chilly 35–39°F (2–4°C), and the pressures so extreme that only highly adapted animals can survive.

The dark zone is defined as continuing down to the abyssal plain, below 13,100 ft (4,000 m). Technically, all the water below 3,300 ft (1,000 m) is a dark zone, where the only light comes from bioluminescent animals (see p.224). However, for convenience, the waters below the dark zone can be further subdivided.

ABYSSAL ZONE 13,100–19,700 ft
Beyond the continental slope, the sea bed flattens out. In many areas, it forms vast plains at depths below 13,100 ft (4,000 m). Some areas drop deeper to a sea floor that undulates down to depths of 19,700 ft (6,000 m). Around 30 percent of the total seabed area lies between these depths. Animals living here move up and down through a narrow column above the seabed, called the abyssal zone.

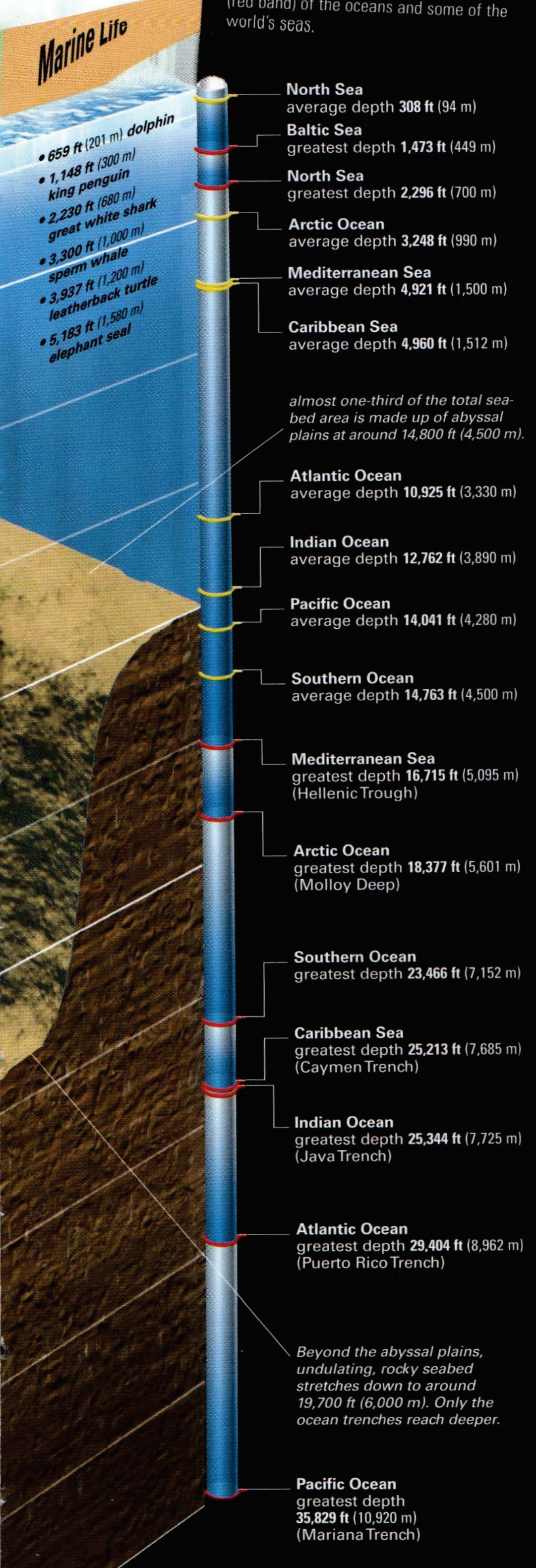
HADAL ZONE 19,700–36,100 ft
The sea floor plunges below 19,700 ft (6,000 m) in only a few deep ocean trenches. This hadal zone makes up less than 2 percent of the total seafloor area. Only two human beings have ever visited this zone (see p.183), and the pressures are so high that only a few uncrewed submersibles are able to operate here.

We therefore know very little about what lives in these great depths, although a fish has been dredged from a depth of 27,500 ft (8,370 m) and shrimplike amphipods have been photographed 35,797 ft (10,911 m) down. Some animals here may require the high pressure at these depths in order to survive.



DEEPEST OCEAN POINTS

The column below shows the average depth (yellow band) and greatest depth (red band) of the oceans and some of the world's seas.



ZONES OF LIFE
The different zones of life in the deep ocean are shown here, together with the depths reached by humans and a selection of marine animals. Most life is concentrated above 3,300 ft (1,000 m), where there is some light.

CRYSTAL WATERS
Crystal-clear tropical waters look idyllic, but the clarity indicates that there are few nutrients and therefore few phytoplankton in the water. As a result, feeding for animals is quite poor.

THE SUNLIT ZONE

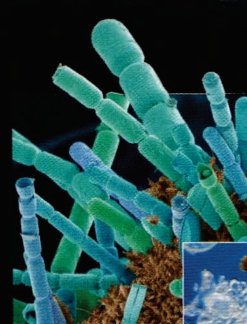
The sunlit zone is the range in which there is enough sunlight for photosynthesis. The ocean absorbs different wavelengths of sunlight to differing extents (see p.38). Nearly all red light is absorbed within 30 ft (10 m), so red animals look black below this depth. Green light penetrates much deeper in clear water, down to around 330 ft (100 m), and blue light to twice that. Due to the presence of chlorophyll, phytoplankton preferentially absorb the red and blue portions of the light spectrum (for photosynthesis) and reflect green light. They can photosynthesize down to about 660 ft (200 m) in clear water.

In cloudy water, the sunlit zone is shallower, because light is absorbed more quickly. The accumulations of phyto- and zooplankton in fertile waters absorb sunlight, reducing the depth of the sunlight zone. Phytoplankton must stay in the sunlit layer during daylight to photosynthesize. Zooplankton follows them there to feed, along with animals that feed on zooplankton. This zone is dangerous because light makes animals conspicuous to their hunters.

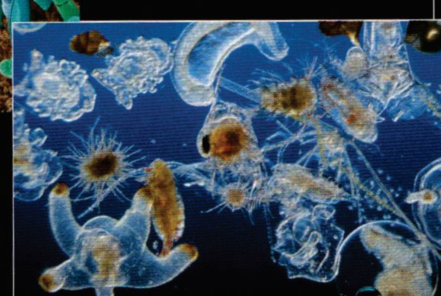
FEEDING IN THE SUNLIT ZONE
The phytoplankton of the sunlit zone is the food of zooplankton. Larger animals, such as these shrimp, in turn feed on zooplankton. Phytoplankton is at the bottom of most ocean food chains.

LIVING IN THE SUNLIT ZONE

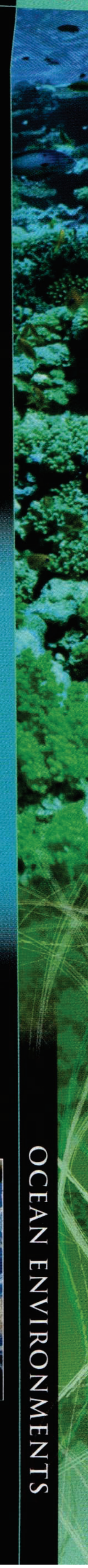
Phytoplankton must remain in the sunlit zone if it is to catch enough sunlight for photosynthesis. This zone is the warmest and richest in the nutrients needed for growth.
It would be counterproductive to expend huge amounts of energy to stay in this zone, so phytoplankton has developed a wide range of mechanisms to help it hang there effortlessly. Buoyancy bubbles, droplets of oil, or stores of light fats keep some species afloat. Others are covered in spines, which increase their surface area and help buoy them up. Some phytoplankton forms colonial chains, which produce more drag in water and slow the rate at which the phytoplankton sink. One group, called dinoflagellates, have threadlike flagellae that let them swim weakly. In this highly productive zone, phytoplankton produces half of the oxygen in the atmosphere. In temperate regions, phyto-plankton proliferates in summer, sometimes forming dense blooms.



DIATOM
Diatoms are a very prolific type of phytoplankton. Some grow colonially, attached to rocks in chains or mats. Each year, six billion tons of phytoplankton grow in the oceans worldwide.



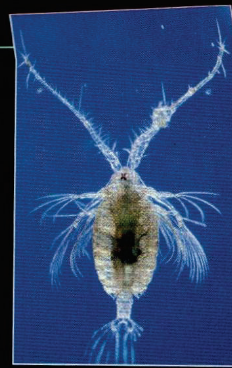
ZOOPLANKTON
This sample of zooplankton, collected in a net, includes an echinoderm (bottom left), a radiolarian, and a crab larva (center), with a fish egg (bottom right).



PLANKTON AND NEKTON

In spring, as phytoplankton blooms begin to develop, zooplankton start multiplying. They follow the phytoplankton into the sunlit zone to feed. Most are herbivores that feed on phytoplankton; some are carnivores that hunt other zooplankton. Many are classed as meroplankton—the young of animals like crabs, lobsters, barnacles, and some fish—which have a planktonic larval stage and use the currents to spread. By taking advantage of the summer phytoplankton feast, they avoid competing for food with adults of their own kind. While plankton drift with the currents, many free-swimming animals (collectively called nekton) gather to feed on them: fish, squid, marine mammals, and turtles. These, in turn, are food for predatory fish and seabirds. Some larger animals, such as basking sharks, also feed on zooplankton and nekton.

SARGASSUMFISH
Here, two Sargassumfish are hiding in *Sargussum* seaweed, floating on the surface of the Sargasso Sea.



COPEPOD
Copepods are herbivores. They make up 70 percent of the total zooplankton population, with thousands in a cubic yard.

THE TWILIGHT ZONE

In the twilight zone, there is just enough light for animals to see—and be seen. As a result, predators and prey are in constant battle. Many species are almost totally translucent, to avoid casting even a faint shadow. Others are reflective, to disguise themselves against the light from above, or have wafer-thin bodies that reduce their silhouette. To cope with dim light, many animals in this zone have large eyes.

The main source of food here is detritus. Many animals therefore migrate upward into the sunlit zone, where food is plentiful, at night, returning to the twilight zone as the Sun rises. Millions of tonnes of animals, equivalent to around 30 per cent of the total marine biomass, make this daily trek—by far the largest migration of life on Earth. The length of the journey is a matter of scale. Small planktonic animals measuring less than 1mm ($^{1}/_{25}$in) in length may only migrate through 20m (70ft), but some larger shrimp travel 600m (2,000ft) each way, every day.

GIANT FILTER-FEEDER
More than 36 ft (11 m) long, basking sharks like this one scoop up shoals of plankton, then filter them from the water with the white gill rakers inside their jaws.

THE DARK AND ABYSSAL ZONES

The waters below the twilight zone are all dark, cold, subject to high pressure, and impoverished in food. For animals adapted to these deep zones, pressure is not a problem: their liquid-filled bodies are almost incompressible, compared to the gas-filled bodies of surface-living birds and mammals, which are much more easily compressible and subject to the effects of pressure. Most fish use gases in their swim bladders to maintain buoyancy, and these are susceptible to pressure change. Many deep-water fish therefore have no functional swim bladders.

For most deep-water species, lack of food is the biggest problem: only about five percent of the energy that plants produce at the surface filters down to these depths. Animals of the deep are typically slow-moving, slow-growing, and long-lived. They conserve energy by waiting for food to come to them. Many therefore have massive mouths and powerful teeth. Others use tricks to catch prey: anglerfish dangle lures, and some species even harbor luminescent bacteria or use chemical processes to make these lures and other structures glow.

SQUID OF THE OPEN OCEAN
Squid live in several zones of the ocean, from the sunlit zone, where this big-fin reef squid is found, to the deep zone. Deep-sea squid are difficult to photograph and are often photographed only as dead specimens.

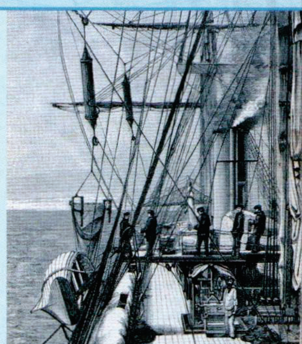
SPOOKFISH
The brownsnout spookfish is found at depths of up to 3,300 ft (1,000 m), on the boundary of the dark zone. Its bones are so thin that it is almost transparent, and its large eyes look upward to spot predators attacking from above. It feeds mainly on copepods, and gives birth to live young that float in the plankton.

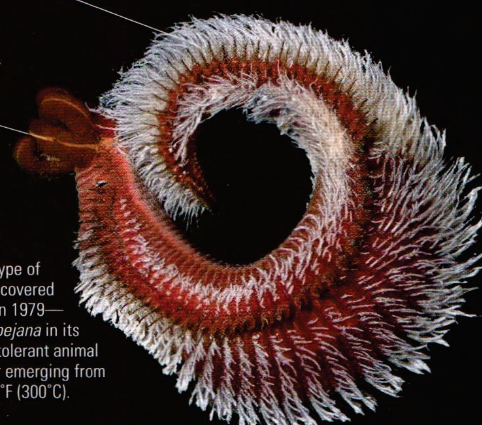
DISCOVERY

THE *CHALLENGER*

Many oceanographic discoveries were made by HMS *Challenger*, a converted British warship that made a 68,900-mile (110,900 km-) voyage around the oceans from 1872 to 1876, collecting depth soundings as it went.

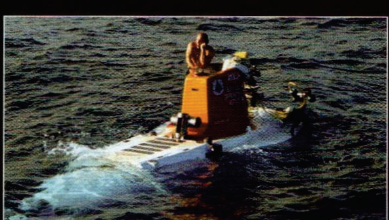
In March 1875, near Guam, it dropped a sounding line to a depth of 26,850 ft (8,184 m) and collected clay to prove this was the seabed. By good luck, the ship was over the Mariana Trench, close to the deepest spot in the ocean, now appropriately called the Challenger Deep.





HEAT-TOLERANT WORM
This polychaete worm (a type of segmented worm) was discovered by the *Alvin* submersible in 1979—and named *Alvinella pompejana* in its honor. It is the most heat-tolerant animal on Earth, living near water emerging from hydrothermal vents at 570°F (300°C).

DEEP SQUEEZE
A polystyrene cup attached to the outside of a submersible resurfaces at a fraction of its original size, illustrating the effects of pressure in the deep ocean.



***ALVIN* SUBMERSIBLE**
Alvin is designed to withstand the extreme pressure of the deep zone and has enabled scientists to make many important discoveries during over 4,000 dives.

THE HADAL ZONE

Few deep-water species have been observed in their natural environment of the hadal zone and even fewer photographed. Many species are known only from samples dredged up in nets, and most photographs are of dead specimens (including the fangtooth on the right). Sometimes deep-sea animals can be studied in aquariums, but many species cannot survive temperature and pressure changes when brought to the surface.

Although many of the animals here hunt each other, the food chain must begin with a supply of food from above. Whereas animals on the seabed can patrol large areas to find food particles accumulated there over weeks and months, animals in midwater must grab food particles in the short time when they float downward past them, which is much trickier. Only a small proportion of the detritus from above is harvested in midwater, so food is always scarce.

Scientists observing this zone often see the same species repeatedly. The environment of this zone is remarkably uniform worldwide and there are few physical or ecological barriers to block the movement of species. Many deep-water species therefore are widely distributed, and several are found in every ocean. As a result, species diversity is low: only around 1,000 of the known 29,000 fish species live at this depth.

FANGTOOTH FISH
The fangtooth has been recorded at depths of 16,380 ft (4,992 m). Like many deep-water fish, it has a large head and massive teeth. Sensory organs along its body detect prey movement in the dark.