MOLLUSKS

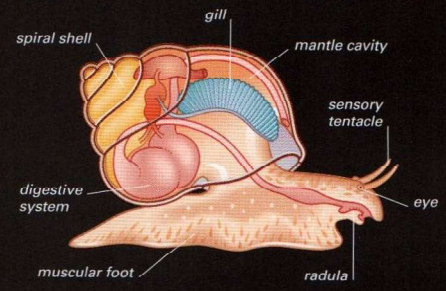
DOMAIN	Eucarya
KINGDOM	Animalia
PHYLUM	Mollusca
CLASSES	8
SPECIES	50,000

AMONG THE MOST SUCCESSFUL of all marine animals, mollusks display great diversity and a remarkable range of body forms, allowing them to live almost everywhere from the ocean depths to the splash zone. They include oysters, sea slugs, and octopuses. Some species lack eyes and shells and live passively in sediment or on the seabed. Others are intelligent, active hunters with complex nervous systems and large eyes. Filter-feeding mollusks, such as clams, are crucial to coastal ecosystems, as they provide food for other animals and improve water quality and clarity. Many mollusks are commercially important for food, pearls, and their shells.

ANATOMY

Most mollusks have a head, a soft body mass, and a muscular foot. The foot is formed from the lower body surface and helps it to move. Mollusks have what is called a hydrostatic skeleton—their bodies are supported by internal fluid pressure rather than a hard skeleton. All mollusks have a mantle, a body layer that covers the upper body and may or may not secrete a shell. The shell of bivalves (clams and relatives) has two halves joined by a hinge; these can be held closed by powerful muscles while the tide is out, or if danger threatens. Mollusks other than bivalves have a rasping mouthpart, or radula, which is unique to mollusks. Cephalopods (octopuses, squid, and cuttlefish) also have beaklike jaws as well as tentacles, but most lack a shell, while most gastropods (slugs and snails) have a single shell. This is usually a spiral in snails, but can be cone-shaped in other forms, such as limpets.

REEF-DWELLING GOLIATH
The tropical giant clam is the largest bivalve and may measure more than 3 ft (1 m) across and weigh over 440 lb (220 kg)

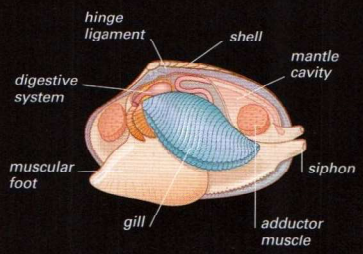


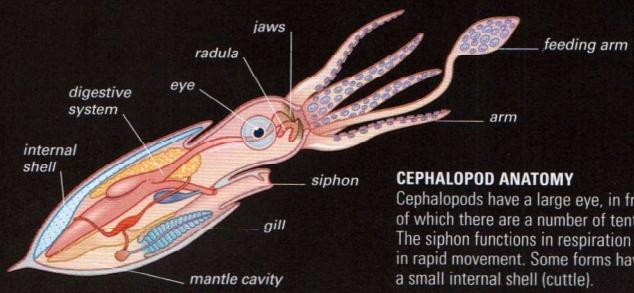
SPIRAL SNAIL SHELL

GASTROPOD ANATOMY
The body plan (far left) of gastropods (slugs and snails) features a head, large foot, and usually a spiral shell (left). In shelled forms, all the soft body parts can be withdrawn into the shell for protection, or to conserve moisture while uncovered by the outgoing tide.

BIVALVE ANATOMY
Bivalves are housed within a shell of two halves (right) from which the siphons and muscular foot can be extended. The shell is opened and closed by the adductor muscles, labeled in the body plan (far right).

BIVALVE SHELL





CEPHALOPOD ANATOMY
Cephalopods have a large eye, in front of which there are a number of tentacles. The siphon functions in respiration and in rapid movement. Some forms have a small internal shell (cuttle).

SENSE ORGANS

Touch, smell, taste, and vision are well developed in many mollusks. The nervous system has several paired bundles of nervous tissue (ganglia), some of which operate the foot, and interpret sensory information such as light intensity. Photoreceptors range from the simple eyes (ocelli) seen along the edges of the mantle or on bivalve siphons, to the sophisticated image-forming eyes of cephalopods. Cephalopods are also capable of rapidly changing their color according to their mood or surroundings.

PIGMENTED SKIN CELLS HELP CUTTLEFISH TO CHANGE COLOR

1 The giant cuttlefish's color change is due to skin cells called chromatophores. It is pale when pigment is confined to a small area of each cell.

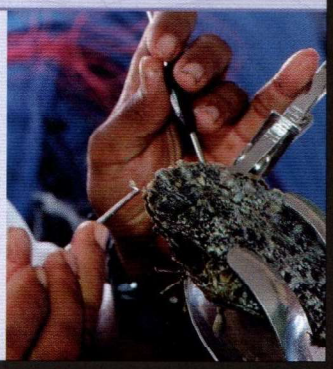
2 When the cuttlefish passes over a darker background, it disperses the colored pigments throughout each of its chromatophores, and the animal darkens.

MOLLUSCAN BEAUTY
Displaying fabulous warning colors, this nudibranch is a shell-less example of the many thousands of marine species of gastropods (slugs and snails).

HUMAN IMPACT

GRAFTING OYSTERS

Pearls form in oysters when a grain of sand or other irritant lodges in their shells. The oyster coats the grain with a substance called nacre, forming a pearl. Today many pearls are cultured artificially: the shell is opened just enough to introduce an irritant into the mantle cavity.



SEEDING AN OYSTER
The best-shaped artificial pearls are produced by "seeding" oysters with a tiny pearl bead and a piece of mantle tissue from another mollusk.

MOVEMENT

Mollusks move in many different ways. Most gastropods glide across surfaces using their mucus-lubricated foot. Exceptions include the sea butterfly, which has a modified foot with finlike extensions for swimming. Some bivalves, such as scallops, also swim, producing jerky movements by clapping the two halves of their shell together. Other bivalves burrow by probing with their foot and then pulling themselves downward by muscular action. Cephalopods are efficient swimmers; some have fins on the sides of their bodies that let them hover in the water, and they can accelerate rapidly by squirting water out through their siphons.

REDUCING DRAG
Swimming backward reduces drag from the tentacles. The siphon, used for jet propulsion, is clearly visible in this Humboldt squid.

AIDED BY MUCUS
Muscular contractions ripple through the fleshy foot of this marine snail. It secretes a lubricating mucus that helps it to move on rough surfaces.

RESPIRATION

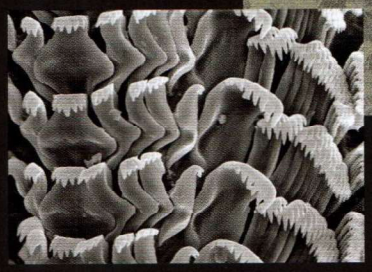
Most mollusks "breathe" using gills, called ctenidia, which are situated in the mantle cavity. They are delicate structures with an extensive capillary network and a large surface area for gaseous exchange. In species that are always submerged, water can continually be drawn in and over the gills. Those living in the intertidal zone are exposed to the air for short periods and must keep their gills moist. At low tide, bivalves close their shells but retain a little water inside. Some gastropods also clamp down against rocks to retain moisture, but pulmonate snails have lost their ctenidia and instead have a lung formed from the mantle cavity. They take in air while exposed and respire through their skin while immersed. The respiratory pigment in most molluscan blood is a copper compound called hemocyanin. It is not as efficient at taking up oxygen as hemoglobin and gives mollusks' blood a blue color.

COLOR CODING
Nudibranchs (sea slugs) have feathery external gills toward the rear of their bodies. The warning coloration of this species includes the bright orange gills.

FEEDING

The ways in which mollusks feed are almost as varied as their anatomy. Sedentary mollusks, such as many bivalves including clams and oysters, create water currents through tubular outgrowths of their mantle (siphons). They filter food from the moving water with their mucus-covered gills. Suitably sized particles are then selected and passed to the mouth by bristly flaps called palps. Sea slugs, chitons, and many sea snails graze algae from hard surfaces using their rasplike radula. Radulae have toothlike structures called denticles, many of which are reinforced with an iron deposit for durability. Larger mollusks feed on crustaceans, worms, fish, and other mollusks, which they locate either by scent or, in the case of some cephalopods such as octopuses, by sight. Cephalopods use their suckered arms to capture prey and their parrotlike beak to crush and dismember it. Some squid even appear to hunt in packs and swim in formation over reefs looking for prey.

SPECIES-SPECIFIC DENTICLES
The denticles on a mollusk's radula are often species-specific. This electron micrograph shows the distinctive radula of the gastropod *Sinezona rimuloides*.

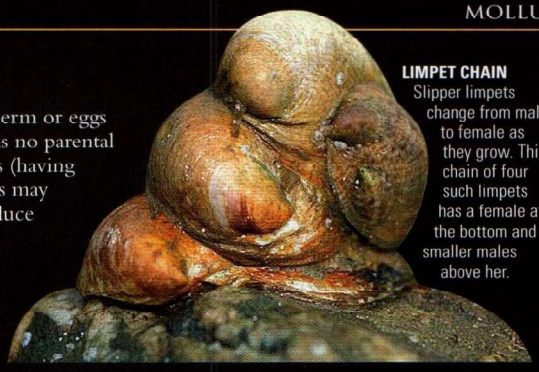


FEEDING TRAIL
Limpets continually graze the same area as the algae on which they feed regrow rapidly. The abrasive radula of the limpet wears a trail on the rock surface, as shown above.

DEVELOPING EMBRYOS
In 4 months, Australian giant cuttlefish eggs develop into mini-replicas of the adults.

REPRODUCTION

In many mollusks, reproduction simply involves releasing sperm or eggs (gametes) into the water. Fertilization is external and there is no parental care. Individuals may be of separate sexes or hermaphrodites (having both male and female reproductive organs). Hermaphrodites may function as either male or female or, as in nudibranchs, produce both eggs and sperm, although eggs can be fertilized only by cross-fertilization. Some species, such as slipper limpets, change sex with age, while oysters can change sex several times in a breeding season. Among cephalopods, males court females, fertilization is internal, and in some species, the eggs are protected by the females until they hatch.



LIMPET CHAIN
Slipper limpets change from male to female as they grow. This chain of four such limpets has a female at the bottom and smaller males above her.

HUMAN IMPACT

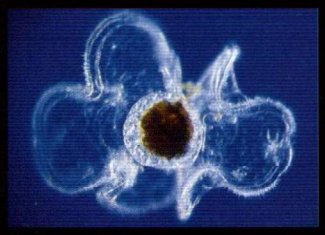
OYSTER DEMAND

Oysters have long been harvested as a food source. Their high market value and increasing demand has led to overexploitation of wild stocks. In the North Sea, the common oyster has vanished from much of its former range, and today most oysters are commercially farmed.

SLOW RECOVERY PERIOD
Relatively long-lived and reproducing only sporadically, the common oyster (right) takes a long time to recover from overexploitation.

LIFE CYCLES

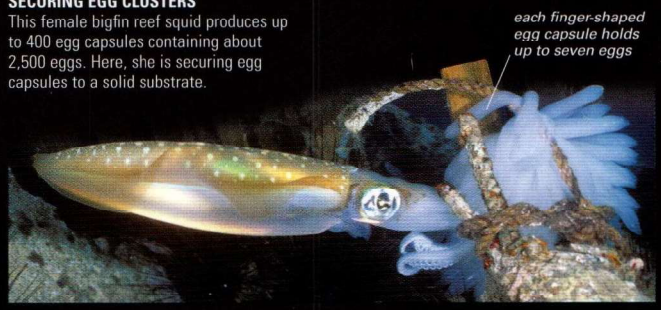
Most mollusks produce eggs that either float or are deposited in clusters, anchored to the substrate. Most forms have eggs that hatch into shell-less larvae, which live in the plankton. The larvae are called ciliated trochophores due to their bands of hairlike cilia, used in swimming. In gastropods, bivalves, and scaphopods, the trochophore larvae change into veliger larvae, which have larger ciliated bands, and sometimes adult features such as a mantle or a rudimentary shell or both. As they approach maturity, the larvae float down from the surface and, on reaching the seabed, change into adults. Only those that land in a suitable environment survive to reach sexual maturity. Cephalopod eggs hatch into active predators. Some resemble mini-adults; others live in the plankton and initially look and behave differently from the adults.



PLANKTONIC LARVA
The visible bands of this veliger larva of the common limpet beat with tiny hairlike cilia, which are used in locomotion and feeding.

READY AND WAITING FOR PREY
This cuttlefish hovers with its arms outstretched. When prey comes within reach, the two feeding arms, currently contracted and set above the two lower arms, will shoot forward to grab the prey.

SECURING EGG CLUSTERS
This female bigfin reef squid produces up to 400 egg capsules containing about 2,500 eggs. Here, she is securing egg capsules to a solid substrate.



MOLLUSK CLASSIFICATION

The phylum Mollusca is the second-largest animal phylum, comprising over 50,000 species, and their diverse form has led to the identification of eight different classes. The majority of species live in marine habitats, but freshwater and terrestrial species are also numerous.

CAUDOFOVEATES
Class Caudofoveata

About 70 species
These are marine, shell-less, wormlike organisms of deep-water sediments. Their horny outer layer is covered with spines.

SOLENOGASTERS
Class Solenogaster

About 180 species
Another marine class of shell-less, worm-like organisms, solenogasters live in or on the ocean floor. Some lack a radula.

MONOPLACOPHORANS
Class Monoplacophora

8 species
These deep-sea mollusks lack eyes but have a radula and a conelike shell. They are more abundant as fossils than as living species.

TUSK SHELLS
Class Scaphopoda

About 350 species
These animals have a tubular, tapering shell, open at both ends. The head and foot project from the wider end and dig in soft sediments.

BIVALVES
Class Bivalvia

More than 14,000 species
Bivalves, or clams and their relatives, have a hinged shell of two halves, but no radula. Most are sedentary and marine. Siphons create a water current through the shell, aiding feeding and respiration. Sexes are usually separate.

GASTROPODS
Class Gastropoda

More than 35,000 species
Familiar as slugs and snails, these mollusks are marine, freshwater, and terrestrial. They have a spiral shell and a large, muscular foot. The body is twisted 180° so the mantle cavity lies over the head. Many species can retract into their shell; hermaphrodite species are common.

CEPHALOPODS
Class Cephalopoda

About 650 species
Squid, octopuses, and cuttlefish are all cephalopods—fast-moving and intelligent, with a complex nervous system and large eyes. The shell is internal or absent, the head surrounded by arms, with or without suckers. The central mouth has a parrotlike beak and a radula. The sexes are separate.

CHITONS
Class Polyplacophora

About 500 species
Chitons have a uniform structure with a series of plates (usually 8) on their backs enclosed by an extension of the mantle. The underside is dominated by the foot.

CLASS BIVALVIA

Common Mussel

Mytilus edulis

LENGTH
4–6 in (10–15 cm)

HABITAT
Intertidal zones, coasts, estuaries

DISTRIBUTION North and southeastern Atlantic, northeastern and southwestern Pacific

Also called the blue mussel, this edible, black-shelled bivalve attaches itself in large numbers to various substrates using tough fibers called byssal threads. These fibers are extremely strong—five times tougher than a human tendon—and prevent the mussels from being washed away. When the mussel opens its shell, water is drawn in over the gills, or ctenidia, which absorb oxygen into the tissues and also filter food particles out of the water.

Common mussels are very efficient filter feeders—they process about 10–18 gallons (45–70 liters) of water per day and consume almost everything they trap. The sexes are separate and so grouping together in "beds" helps to ensure that their eggs are fertilized. After hatching, the planktonic larvae are dispersed by the ocean currents. After about three months, they settle and mature further before moving once again to join the adult population.

CLASS BIVALVIA

Great Scallop

Pecten maximus

WIDTH
Up to 7½ in (17 cm)

HABITAT
Sandy seabeds, at 16–500 ft (5–150 m), commonly 33 ft (10 m)

DISTRIBUTION Northeastern Atlantic

Also known as the king scallop, the great scallop is usually found partly buried in sand. It is one of the few bivalves capable of rapid movement through water, which it achieves using a form of jet propulsion. It claps the two halves of its shell together, which pushes water out of the mantle cavity close to the hinge. It moves forward with its shell gape first, producing jerky movements as it takes successive "bites" of water. These odd movements may be a useful strategy to escape from predators. These edible bivalves are now farmed to meet growing demand.

CLASS BIVALVIA

Black-lip Pearl Oyster

Pinctada margaritifera

LENGTH
Up to 12 in (30 cm) diameter

HABITAT
Hard substrata of inter- and subtidal zones; reefs

DISTRIBUTION Gulf of Mexico, western and eastern Indian Ocean, western Pacific

Black-lip pearl oysters begin life as a male before changing into a female two or three years later. Females produce millions of eggs, which are fertilized randomly and externally by the males' sperm, before hatching into free-swimming larvae. The mobile larvae pass through various larval stages for about a month before eventually settling on the seafloor, after metamorphosing into the sessile (immobile) adult form. This species is famous and much sought-after because it occasionally produces prized black pearls.

CLASS BIVALVIA

Atlantic Thorny Oyster

Spondylus americanus

LENGTH
Up to 4½ in (11 cm)

HABITAT
Rocks to a depth of 460 ft (140 m)

DISTRIBUTION Southeast coast of US, Bahamas, Gulf of Mexico, Caribbean

The Atlantic thorny oyster's spiny shell protects it from predators. The oyster pictured here is covered with an encrusting red sponge, which provides camouflage. This species is unusual in having a ball-and-socket type hinge joining the two halves of its shell,

rather than the more common toothed hinge seen in many other bivalves. The Atlantic thorny oyster cements itself directly to rocks rather than using byssal threads.

ORDER BIVALVIA

Shipworm

Teredo navalis

LENGTH
24 in (60 cm)

HABITAT
Wood burrows in high-salinity seas and estuaries

DISTRIBUTION Coastal waters off North, Central, and South America, and Europe

Despite its wormlike appearance, the shipworm is a type of clam that has become elongated as an adaptation to its burrowing lifestyle. Its bivalve shell, situated at the anterior end, is very small and ridged. The shipworm uses it with a rocking motion to bore into wooden objects. Outside the shell its body is unprotected, except for a calcareous tube it secretes to line the burrow. These worms damage wooden structures, such as piers, and in the past caused many ships to sink. The burrow entrance is only about the size of a pinhead, but the burrow itself may be over ½ in (1 cm) wide, so the extent of an infestation is often underestimated until it is too late.

Shipworms change from male to female during their lifetime, and the female form produces many eggs, from which free-swimming larvae hatch. When they mature and settle on a suitable piece of wood, the larvae quickly metamorphose into the adult form and start burrowing.

ORDER BIVALVIA

Common Piddock

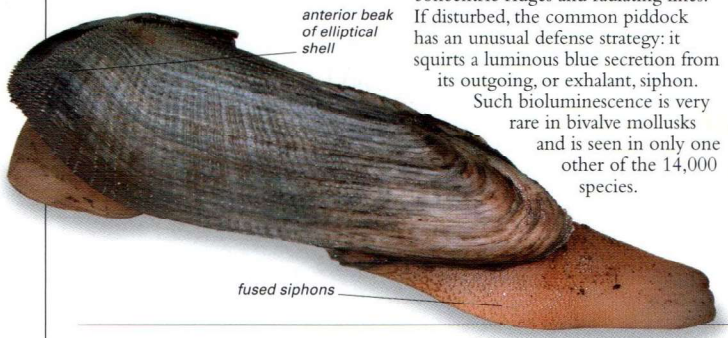
Pholas dactylus

LENGTH
Up to 6 in (15 cm) across

HABITAT
Lower shore to shallow sublittoral

DISTRIBUTION South and east coasts of UK, Severn estuary in UK, west coast of France, Mediterranean

This mollusk has a pronounced "beak" covered in toothlike projections at the front end of its shell. It uses this feature for boring holes into relatively soft substrates, such as mud, chalk, peat, and shale. Like the shipworm (opposite), this piddock relies on its burrows for protection from predation, because the shell does not encase all of its body—its two fused siphons (tubes for eating, breathing, and excretion) trail out behind it. The shell is fragile, elliptical, and covered in a pattern of concentric ridges and radiating lines. If disturbed, the common piddock has an unusual defense strategy: it squirts a luminous blue secretion from its outgoing, or exhalant, siphon. Such bioluminescence is very rare in bivalve mollusks and is seen in only one other of the 14,000 species.



ORDER BIVALVIA

Common Edible Cockle

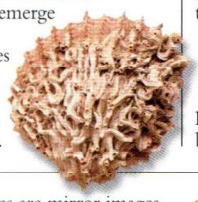
Cerastoderma edule

LENGTH
Up to 2 in (5 cm)

HABITAT
Middle and lower shore, 2 in (5 cm) below surface of sand or mud

DISTRIBUTION Barents Sea, eastern north Atlantic from Norway to Senegal, West Africa

This edible bivalve has a robust, ribbed shell and burrows in dense populations just below the surface of sand or mud, filtering organic matter such as plankton from the water. Free-swimming larvae emerge from its fertilized eggs. Adult cockles sink to the sea floor, where they assume a more sedentary lifestyle.



ORDER BIVALVIA

Razor Shell

Ensis americanus

LENGTH
6 in (16 cm)

HABITAT
Sandy and muddy shores

DISTRIBUTION Atlantic coast of North America, introduced to North Sea

So called because their shells resemble a straight razor, razor shells live in deep, vertical burrows on muddy and soft sandy shores. They are native to the northeast coast of North America, and the free-swimming larval stage is thought to have been introduced to the North Sea in 1978 when a ship emptied its ballast tanks outside the German port of Hamburg. This clam has subsequently spread along the continental coast. In places, it affects local polychaete worm populations, but it is not considered a pest.

ORDER BIVALVIA

Giant Clam

Tridacna gigas

LENGTH
Up to 5 ft (1.5 m)

HABITAT
Sandy beds of reef flats and shallow lagoons to 65 ft (20 m)

DISTRIBUTION Tropical Indo-Pacific from south China seas to northern coasts of Australia, and Nicobar Islands in the west to Fiji in the east

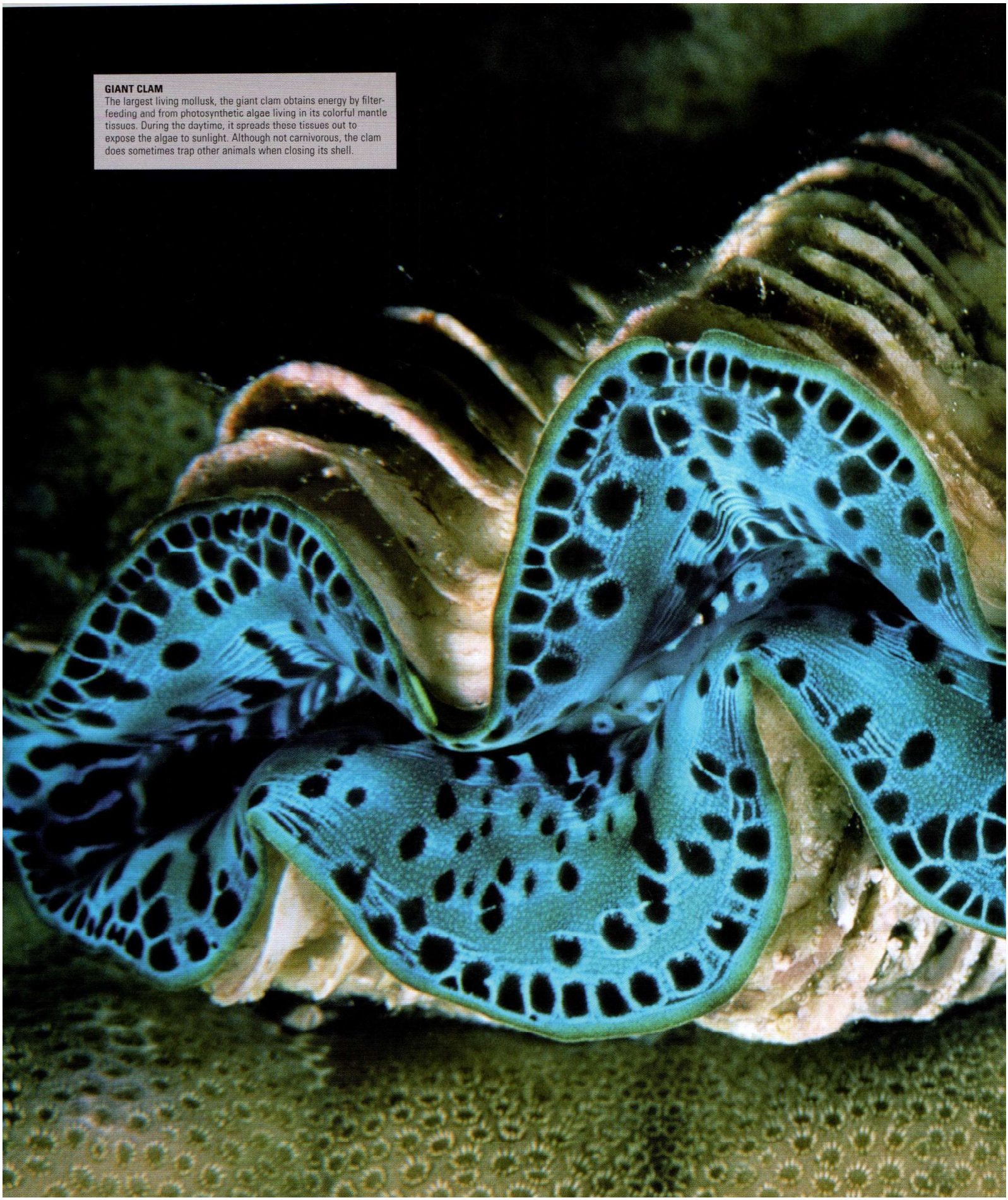
The largest and heaviest of all mollusks is the giant clam. Like other bivalves, it feeds by filtering small food particles from the water using its ingoing, or inhalant, siphon, which is fringed with small tentacles. However, it differs in obtaining most of its nourishment from zooxanthellae (unicellular algae that live within its tissues)—a type of relationship also associated with coral polyps. The algae have a constant and safe environment in which to live; in return, they provide the clam with essential nutrients, the carbon-based products of photosynthesis. In fact, so dependent is the giant clam on these algae that it will die without them.

The adult is sessile (immobile) and its inhalant and exhalant (outgoing) siphons are the only openings in its mantle. Although the scalloped edges of their shell halves are mirror images of one another, larger individuals may be unable to close their shells fully, so their brightly colored mantle and siphons remain constantly exposed.

Many giant clams appear iridescent due to an almost continuous covering of purple and blue spots on their mantles, while others look more green or gold, but all have a number of clear spots, or "windows," that let sunlight filter into the mantle cavity. Fertilization is external and the eggs hatch into free-swimming larvae before settling onto the seabed. The exhalant siphon expels water and at spawning time provides an exit point for the eggs or sperm.

SPAWNING

Reproduction in giant clams is triggered by chemical signals that synchronize the release of sperm and eggs into the water. Giant clams start life as males and later become hermaphroditic, but during any one spawning event, they release either sperm or eggs in order to avoid self-fertilization. A large clam can release as many as 50 million eggs in 20 minutes.



GIANT CLAM
The largest living mollusk, the giant clam obtains energy by filter-feeding and from photosynthetic algae living in its colorful mantle tissues. During the daytime, it spreads these tissues out to expose the algae to sunlight. Although not carnivorous, the clam does sometimes trap other animals when closing its shell.

CLASS GASTROPODA

Common Limpet

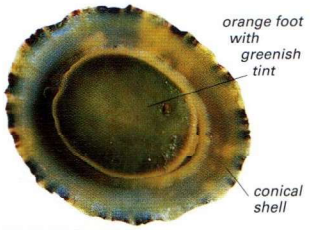
Patella vulgata

DIAMETER
2½ in (6 cm)

HABITAT
Rocks on high shore to sublittoral zone

DISTRIBUTION Northeastern Atlantic from Arctic Circle to Portugal

Abundant on rocks from the high to the low water mark, the common limpet is superbly adapted to shore life. A conical shell protects it from predators and the elements. Limpets living at the low water mark are buffeted by the waves and so require smaller, flatter shells than those living at the high water mark, where wider, taller shells allow for better water retention during periods of exposure. Limpets travel slowly during low tide, covering up to 24 in (60 cm) using contractions of their single foot. They graze on algae from rocks using a radula (a rasplike structure), which has teeth reinforced with iron minerals.



MUSCULAR FOOT
The common limpet's muscular foot, seen here from below, holds it firmly to its rock, regardless of the strength of the waves.

RETURNING HOME
Limpets gradually grind a "scar" into their anchor spot on the rock, to aid their grip and help retain water. A mucus trail leads them back to the spot.

CLASS GASTROPODA

Zebra Nerite

Puperita pupa

LENGTH
Up to ½ in (1 cm)

HABITAT
Rocky tide pools

DISTRIBUTION Caribbean, Bahamas, Florida

The small, rounded, smooth, black-and-white striped shell of the zebra nerite is typical of the species, but in examples from Florida the shell is sometimes more mottled or speckled with black. These gastropods are most active during the day, when they feed on microorganisms such as diatoms and cyanobacteria, but if they become too hot or they are exposed at low tide, they cluster together, withdraw into their shells, and become inactive. This may be a mechanism for preventing excessive water loss.

Unusually for gastropods, there are separate males and females of zebra nerites and fertilization of the eggs occurs internally. The males use their penis to deposit sperm into a special storage organ inside the female. Later, she lays a series of small white eggs that hatch into planktonic larvae.

CLASS GASTROPODA

Dog Whelk

Nucella lapillus

LENGTH
Up to 2½ in (6 cm)

HABITAT
Middle and lower rocky shores

DISTRIBUTION Northwestern and northeastern Atlantic

One of the most common rocky shore gastropods, the dog whelk has a thick, heavy, sharply pointed spiral shell. The shell's exact shape depends on its exposure to wave action, and its color depends on diet. Dog whelks are voracious predators, feeding mainly on barnacles and mussels. Once the prey has been located, the whelk uses its radula to bore a hole in the shell of its prey before sucking out the flesh.

CLASS GASTROPODA

Top Shell

Trochus niloticus

LENGTH
6 in (16 cm)

HABITAT
Intertidal and shallow subtidal areas, reef flats to 23 ft (7 m)

DISTRIBUTION Eastern Indian Ocean, western and southern Pacific

Easily distinguished from most other gastropods by the conical shape of its spiral shell, the top shell moves slowly over reef flats and coral rubble, feeding on algae. Demand for its flesh and pretty shell has led to declining numbers, especially in the Philippines, due to unregulated harvesting. It has, however, been successfully introduced elsewhere in the Indo-Pacific, such as French Polynesia and the Cook Islands, from where some original sites are being restocked.

CLASS GASTROPODA

Red Abalone

Haliotis rufescens

LENGTH
6–8 in (15–20 cm)

HABITAT
Rocks from low tide mark to 100 ft (30 m)

DISTRIBUTION East Pacific coasts from southern Oregon, US to Baja California, Mexico

The largest of the abalone species, the red abalone is so called because of the brick-red color of its thick, roughly oval shell. There is an arc of three to five clearly visible holes in the shell, through which it respires and expels waste products. These are filled and replaced with new holes as the abalone increases in size. Sea otters are one of the red abalone's main predators, along with human divers.

CLASS GASTROPODA

Venus Comb

Murex pecten

LENGTH
Up to 3 in (8 cm)

HABITAT
Tropical warm waters to 650 ft (200 m)

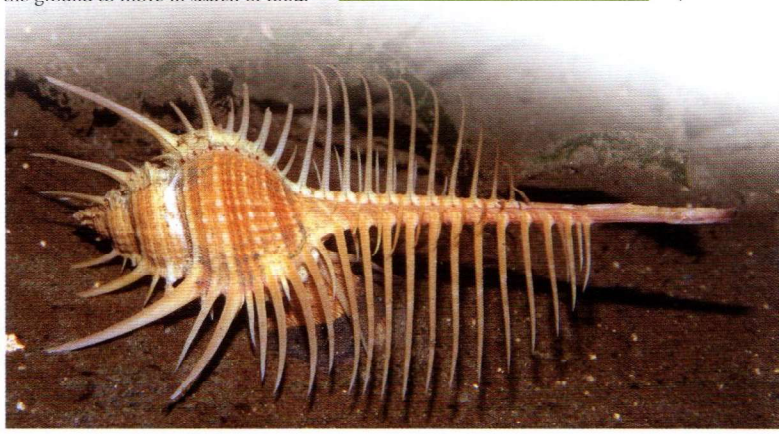
DISTRIBUTION Eastern Indian Ocean and western Pacific

The tropical carnivorous snail known as the Venus comb has a unique and spectacular shell. There are rows of long, thin spines along its longitudinal ridges, which continue onto the narrow, rodlike, and very elongated siphon canal. The exact function of these spines is unknown, but they are thought to be either for protection or to prevent the snail from sinking into the soft substrate on which it lives. Its body is tall and columnar so that it can lift its cumbersome shell above the ground to move in search of food.

HIDING FROM VIEW

There are times when the Venus comb buries itself just below the surface of the sea floor, displacing the sand with movements of its muscular foot. However, it leaves the opening of its tubular inhalant siphon above the sand's surface so that it can draw water into its mantle cavity to obtain oxygen and to "taste" the water for the presence of prey.

HALF BURIED
The spines of this Venus comb can be seen sticking out of the sand. The siphon is visible to the right of the picture.



CLASS GASTROPODA

Tiger Cowrie

Cypraea tigris

LENGTH Up to 6 in (15 cm)

HABITAT Low tide to 100 ft (30 m) on coral reefs

DISTRIBUTION Indian Ocean, western Pacific

One of the largest cowrie species, the tiger cowrie has a shiny, smooth, domed shell with a long, narrow aperture, and is variously mottled in black, brown, cream, and orange. Extensions of the cowrie's mantle (its body's outer, enclosing layer) cover parts of the exterior of the shell. These extensions have numerous projections, or papillae, whose exact function is unknown, but which may increase the surface area for oxygen absorption or provide camouflage of some sort. Tiger cowries are nocturnal creatures, hiding in crevices among the coral during the day and emerging at night to graze on algae. The sexes are separate and fertilization occurs internally. Females exhibit some parental care in that they protect their egg capsules by covering them with their muscular foot until they hatch into larvae, which then enter the plankton to mature.

CLASS GASTROPODA

Flamingo Tongue

Cyphoma gibbosum

LENGTH 1–1½ in (3–4 cm)

HABITAT Coral reefs at about 50 ft (15 m)

DISTRIBUTION Western Atlantic, from North Carolina to Brazil; Gulf of Mexico, Caribbean Sea

The off-white shell of the flamingo tongue cowrie is usually almost completely hidden by the two fleshy, leopard-spotted extensions of its body's outer casing, or mantle. When threatened, however, its distinctive coloration quickly disappears as it withdraws all its soft body parts into its shell for protection. This snail feeds almost exclusively on gorgonian corals, which dominate Caribbean reef communities. Although these corals release chemical defenses to repulse predators, the flamingo tongue cowrie is apparently able to degrade these bioactive compounds and eat the corals without coming to any harm. After mating, the female strips part of a soft coral branch and deposits the egg capsules on it. Each capsule contains a single egg that will hatch into a free-swimming planktonic larva.

CLASS GASTROPODA

Giant Triton

Charonia tritonis

LENGTH Up to 16 in (40 cm)

HABITAT Coral reef, sandy substrate, intertidal and subtidal zones

DISTRIBUTION Indian Ocean, western and central Pacific

This gastropod is one of the very few animals that eats the crown-of-thorns starfish, itself a voracious predator and destroyer of coral reefs. The giant triton is an active hunter that will chase prey, such as starfish, mollusks, and sea stars, once it has been detected. It uses its muscular single foot to hold its victim down while it cuts through any protective covering using its serrated, tonguelike radula; it then releases paralyzing saliva into the body before eating the subdued prey.

CLASS GASTROPODA

Common Periwinkle

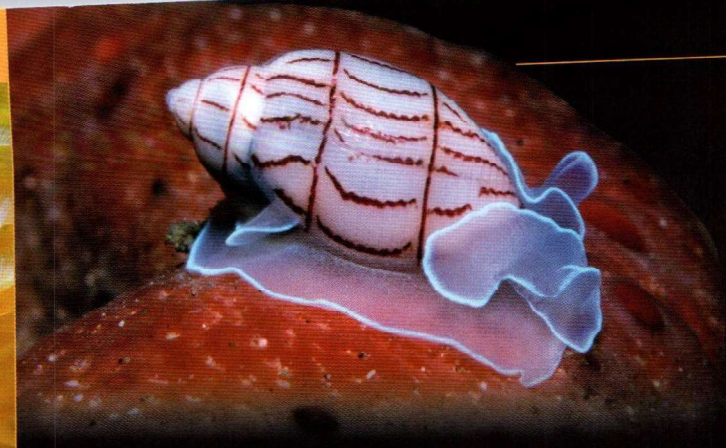
Littorina littorea

LENGTH Up to 1 in (3 cm)

HABITAT Upper shore to sublittoral rocky shores, mud flats, estuaries

DISTRIBUTION Coastal waters of northwest Europe; introduced to North America

The common periwinkle has a black to dark gray, sharply conical shell and slightly flattened tentacles, which in juveniles also have conspicuous black banding. The sexes are separate and fertilization occurs internally. Females release egg capsules, containing two or three eggs, directly into the water during the spring tides. The eggs hatch into free-swimming larvae that float in the plankton for up to six weeks. After settling and metamorphosing into the adult form, it takes a further two to three years for the adult to fully mature. It feeds mainly on algae, which it rasps from the rocks. Recently, the common periwinkle was accidentally introduced into North America, where its selective grazing of fast-growing algal species has considerably affected the ecology of some rocky shores.



CLASS GASTROPODA

Bubble Shell

Bullina lineata

LENGTH
1 in (2.5 cm)

HABITAT
Sand, reefs to 65 ft (20 m), mainly intertidal; subtidal at range limits

DISTRIBUTION Tropical and subtropical waters of Indian Ocean and west Pacific

The pale spiral shell of the bubble shell (also known as the red-lined bubble shell) has a distinctive pattern of pinkish red lines by which it can be identified. Its soft body parts are delicate and translucent with a fluorescent blue margin and, in form, reminiscent of the Spanish dancer (opposite), which is a close relative that has lost its shell. If threatened, the bubble shell quickly withdraws into its shell and at the same time regurgitates food, possibly as a defense mechanism to distract predators. The bubble shell is itself a voracious predator, feeding on sedentary polychaete worms. This mollusk is hermaphroditic and produces characteristic spiral white egg masses.

CLASS GASTROPODA

Three-tooth Cavoline

Cavolinia tridentata

LENGTH
½ in (1 cm)

HABITAT
330–6,500 ft (100–2,000 m); carried in ocean currents

DISTRIBUTION Warm oceanic waters worldwide

This species of sea butterfly has a small, almost transparent, spherical shell with three distinctive, posterior projections. The shell also has two slits through which large extensions of the mantle pass. These brownish "wings" are ciliated and so can create weak water currents as well as aid buoyancy. Sea butterflies are unusual among shelled mollusks in that they can live in open water. Like other members of this group, the three-tooth cavoline produces a mucus web very much larger than itself, which traps planktonic organisms, such as diatoms and the larvae of other species. It eats the web and the trapped food at intervals, then produces a new one. During their lifetime, sea butterflies change first from males into hermaphrodites and then into females.

CLASS GASTROPODA

Sea Hare

Aplysia punctata

LENGTH
Up to 8 in (20 cm)

HABITAT
Shallow water

DISTRIBUTION Northeast Atlantic and parts of the Mediterranean

The sea hare, a type of sea slug, has tentacles reminiscent of a hare's ears. It has an internal shell about 1½ in (4 cm) long that is visible only through a dorsal opening in the mantle. If disturbed, it releases purple or white ink. It is not known if this response is a defense mechanism.

CLASS GASTROPODA

Polybranchid

Cyerce nigricans

LENGTH
Up to 1½ in (4 cm)

HABITAT
Reefs

DISTRIBUTION Western Indian Ocean, western and central Pacific

This colorful sea slug is a herbivore that browses on algae. It has no need of camouflage or a protective shell, as it has two excellent alternative defense strategies. First, it can secrete distasteful mucus, by utilizing substances in the algae it feeds on and secreting them from small microscopic glands over the body. Second, its body is covered with petal-like outgrowths called cerata, spotted and striped above and spotted below, that can be shed if it is attacked by a predator, in the same way as a lizard sheds its tail. This ability to cast off body parts to distract predators is called autonomy.

The cerata are also used in respiration, their large collective surface area allowing efficient gas exchange with the surrounding water. The head carries two pairs of sensory organs—the oral tentacles near the mouth and, further back, the olfactory organs (rhinophores). These are retractile and subdivide as the polybranchid matures. They are used to assist in finding food and mates. There is some debate as to whether this sea slug is a separate species or is simply a color variation of a similar mollusk, *Cyerce nigra*.

CLASS GASTROPODA

Chromodorid Sea Slug

Chromodoris lochi

LENGTH
1½ in (4 cm)

HABITAT
Reefs

DISTRIBUTION Tropical and subtropical western and central Pacific

Protected from predators by its bright warning coloration and unpleasant taste, the chromodorid sea slug forages in the open, rather than hiding away in cracks and crevices. Since it cannot swim, it glides over the tropical reefs on which it lives on its muscular foot, secreting a mucus trail much as terrestrial slugs do. The different species of the genus *Chromodoris* are distinguished by the pattern of black lines on their backs and the plain color of their gills and rhinophores (a pair of olfactory organs at the head end).

The two chromodorid sea slugs pictured here are possibly about to mate. To do so, they must face in opposite directions so that their sexual openings are aligned. As they are hermaphrodites, they both produce sperm, which they exchange during mating, and both later produce fertilized eggs.

CLASS GASTROPODA

Hermissenda Sea Slug

Hermissenda crassicornis

LENGTH
Up to 3 in (8 cm)

HABITAT
Mud flats, rocky shores

DISTRIBUTION Northwest and northeast Pacific

This sea slug, usually known simply as Hermissenda, has an unusual way of deterring predators. It separates the stinging cells from any organism it eats and stores them in the orange-red tips of petal-like tentacles, or cerata, that cover its back. Any creature that touches the cerata is stung. Unlikely though it seems, Hermissenda is used extensively by scientists conducting memory experiments. The animal has an excellent sense of smell that enables it to find its way around mazes to locate food, and it can be "taught" to respond to simple stimuli.

CLASS GASTROPODA

Spanish Dancer

Hexabranchus sanguineus

LENGTH
Up to 24 in (60 cm)

HABITAT
Shallow water on coasts and reefs

DISTRIBUTION Parts of tropical Indian Ocean, west Pacific

The largest of the nudibranchs is the Spanish dancer—so called because when it swims, the undulating movements of its flattened body are reminiscent of a flamenco dancer. Adults are brightly but variably colored, generally in shades of red, pink, or orange, sometimes mixed with white or yellow. While resting, crawling, or feeding, the lateral edges of its mantle are folded up over its back, displaying the less colorful underside. If disturbed, it will escape by swimming away, exposing its bright colors and possibly startling potential predators. Spanish dancers are specialist predators that feed only on sponges, particularly encrusting species, from which they modify and concentrate certain distasteful compounds in their skin to use as another defense against predation. They have external gills for respiration, which are extensively branched and attached to the body wall in distinct pockets and which cannot be retracted. Like all nudibranchs, the Spanish dancer is hermaphroditic, but it requires a partner in order to reproduce.

external gills

bright coloration

SEA ROSE

To protect its egg cluster from predators, the Spanish dancer deposits with its eggs some of the toxins that it produces for its own defense. Once hatched, the free-swimming larvae join the plankton until they mature. With a life-span of about a year, they grow rapidly, settling on a suitable food source when they are ready to change into the adult form.

EGG RIBBON
Each dancer produces several roselike pink egg ribbons about 1½ in (4 cm) across; together these may contain over one million eggs.

CLASS CEPHALOPODA

Nautilus

Nautilus pompilius

WIDTH
Shell up to 8 in (20 cm)

HABITAT
Tropical open waters to 1,600 ft (500 m)

DISTRIBUTION Eastern Indian Ocean, western Pacific, and Australia to New Caledonia

The six remaining species of *Nautilus* belong to a once numerous group of shelled cephalopods that existed from 400 to 65 million years ago. They are often referred to as "living fossils" because they are so little changed from their ammonoid ancestors. Their shell protects them from predation, while gas trapped in its inner chambers provides buoyancy. The head protrudes from the shell and has up to 90 suckerless tentacles, which are used to capture prey such as shrimp and other crustaceans; the head also features a pair of rudimentary eyes that lack a lens and work on a principle similar to a pinhole camera. The nautilus swims using jet propulsion, drawing water into its mantle cavity and expelling it forcefully through a tubular siphon, which can be directed to propel the nautilus forward, backward, or sideways. Unlike most other cephalopods, nautiluses mature late, at about ten years of age, and produce only about twelve eggs per year.

CLASS CEPHALOPODA

Dumbo Octopus

Grimpoteuthis plena

LENGTH
Up to 8 in (20 cm)

HABITAT
Deep water, to 6,500 ft (2,000 m)

DISTRIBUTION Northwest Atlantic

Little is known about the Dumbo octopus, as only a few have been recorded. Its common name derives from a pair of unusual, earlike flaps extending from the mantle above its eyes. It has a soft body, an adaptation to its deep-water habitat, and eight arms connected to each other almost to their tips by "webbing." Its diet includes worms and snails.

CLASS CEPHALOPODA

Blue-ringed Octopus

Hapalochlaena maculosa

LENGTH
4–8 in (10–20 cm)

HABITAT
Shallow water, rock pools

DISTRIBUTION Tropical west Pacific and Indian Ocean (all species of Hapalochlaena)

The most dangerous cephalopod is the small blue-ringed octopus, which produces highly toxic saliva powerful enough to kill a human. To catch prey, it either releases saliva into the water and waits for the poison to take effect, or catches, bites, and injects prey directly. Its bright coloring is unusual for an octopus, and the numerous blue rings covering its body become more iridescent if it is disturbed.

CLASS CEPHALOPODA

Giant Octopus

Enteroctopus dofleini

LENGTH
Up to 30 ft (9 m)

HABITAT
Bottom dwellers, to 2,500 ft (750 m)

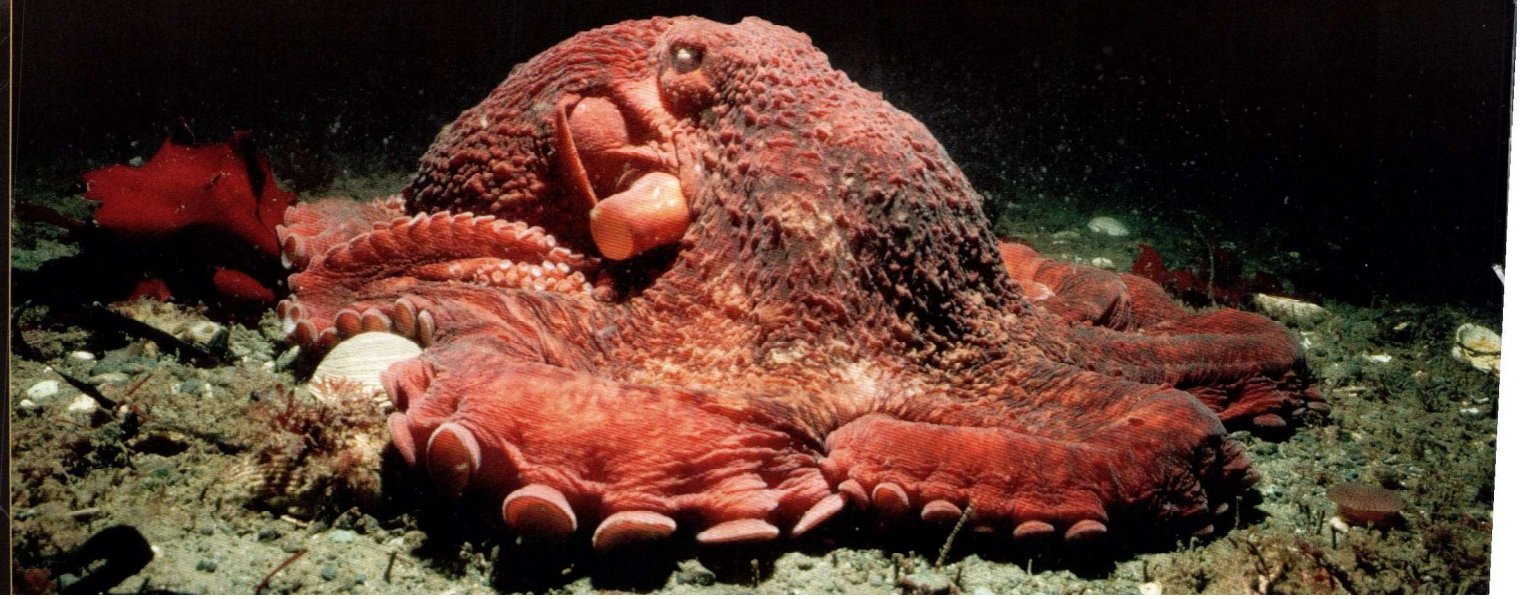
DISTRIBUTION Temperate northwest and northeast Pacific

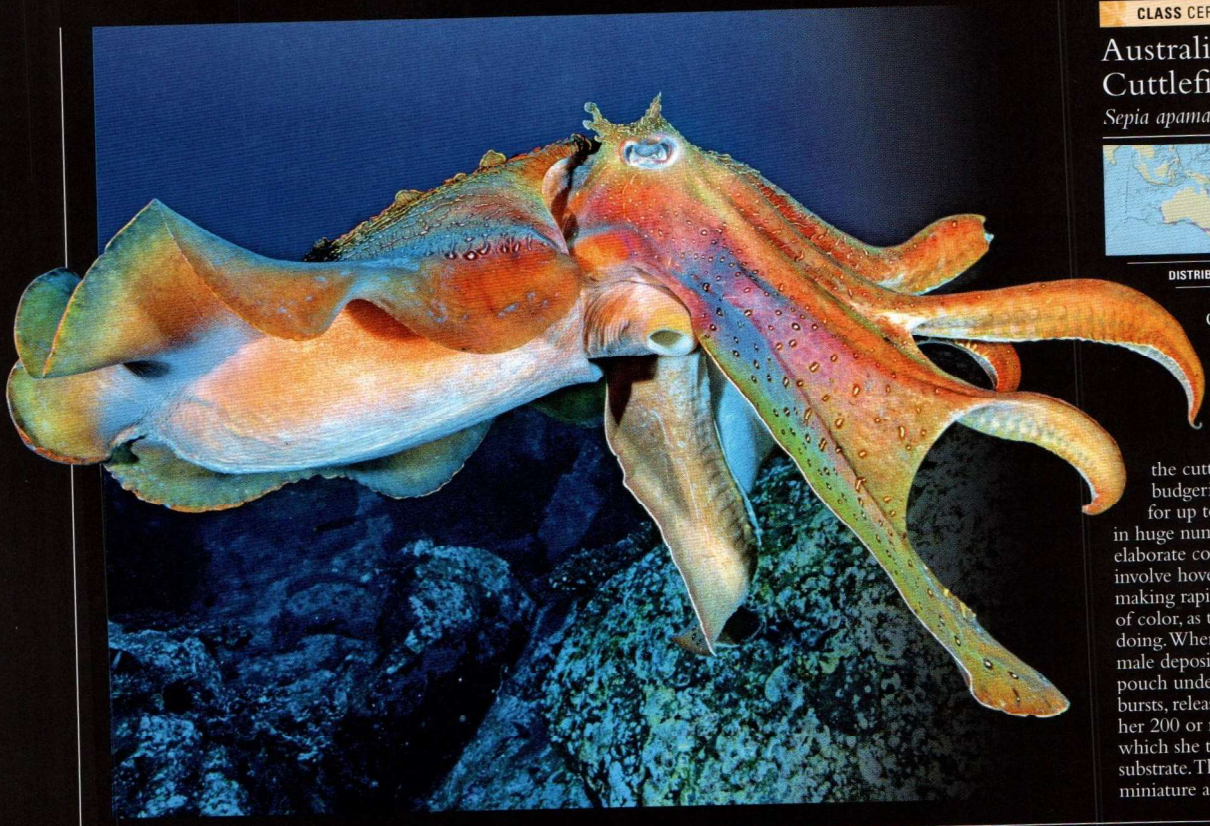
The giant octopus is one of the largest invertebrates as well as one of the most intelligent. It can solve problems, such as negotiating a maze by trial and error, and remember the solution for a long time. It has large, complex eyes with color vision and sensitive suckers that can distinguish between objects by touch alone. It changes color rapidly by contracting or expanding pigmented areas in cells called chromatophores, enabling it to remain camouflaged regardless of background. It also uses its color to convey mood, becoming red if annoyed and pale if stressed. Most cephalopods show little parental care, but female giant octopuses guard their eggs for up to eight months until they hatch. They do not eat during that time, and siphon water over the eggs to keep them clean and aerated.

DEFENSE MECHANISM

When threatened, a giant octopus squirts a cloud of purple ink out through its siphon into the water and at the same time moves backward rapidly using jet propulsion. Potential predators are left confused and disoriented in a cloud of ink. The octopus can repeat this process several times in quick succession.

A QUICK GETAWAY
This giant octopus is making a rapid retreat, expelling an ink jet as a defense mechanism. The jet also propels the octopus backward forcefully.





CLASS CEPHALOPODA

Australian Giant Cuttlefish

Sepia apama

LENGTH Up to 5 ft (1.5 m)

HABITAT Shallow water over reefs

DISTRIBUTION Coastal Australian waters

Of about 100 cuttlefish species, the Australian giant cuttlefish is the largest. Like all cuttlefish, it has a flattened body and an internal shell, known as the cuttle and familiar to many as budgerigar food. This species lives for up to three years and gathers in huge numbers to breed. Males have elaborate courtship displays, which involve hovering in the water while making rapid, kaleidoscopic changes of color, as the male shown here is doing. When a female is receptive, the male deposits a sperm package in a pouch under her mouth. This later bursts, releasing sperm and fertilizing her 200 or more golf-ball-sized eggs, which she then deposits on a hard substrate. The eggs hatch into miniature adults after several months.

CLASS CEPHALOPODA

Common Squid

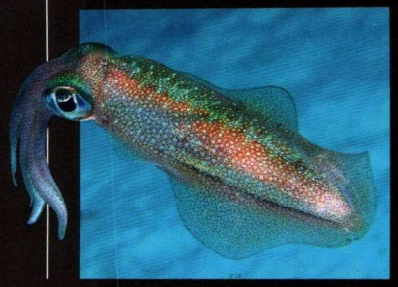
Loligo vulgaris

LENGTH Up to 12 in (30 cm)

HABITAT 60–800 ft (20–250 m)

DISTRIBUTION Eastern Atlantic, Mediterranean

A tubular body and a small, rodlike internal skeleton are characteristic features of all species of squid. They also have very large eyes relative to body size. The common squid is an inshore, commercially important species that has been harvested for centuries and is probably the best known of all cephalopods. It is a fast swimmer that actively hunts its prey, such as crustaceans and small fish. Once caught, the squid passes the prey to its mouth, where it is dismembered by powerful, beaklike jaws.



CLASS CEPHALOPODA

Glass Squid

Teuthowenia pellucida

LENGTH ½–1½ in (1.4–3.8 cm)

HABITAT Midwater

DISTRIBUTION Circumglobal in southern temperate waters

Like many mollusks, juvenile glass squid live in the plankton, then descend to deeper, darker levels as they mature. The presence of light organs, called photophores, in the tips of their arms and in the eye may help in locating a mate. Sexually mature females are also thought to produce a chemical attractant, or pheromone.

CLASS CEPHALOPODA

Vampire Squid

Vampyroteuthis infernalis

LENGTH Up to 15 in (38 cm)

HABITAT 1,600–5,000 ft (500–1,500 m), oxygen-poor water

DISTRIBUTION Tropical and temperate oceans worldwide

This is the only squid that spends its entire life in deep, oxygen-poor water. Like many deep-living creatures, the vampire squid is bioluminescent and has light organs, or photophores, on the tips of its arms and at the base of its fins. If threatened, it flashes these lights and writhes around in the water, finally ejecting mucus that sparkles with blue luminescent light. When the lights go out, the vampire squid will have vanished. Its predators include sea lions and deep-diving whales.

CLASS POLYPLACOPHORA

Lined Chiton

Tonicella lineata

LENGTH 1½ in (3.5 cm)

HABITAT Intertidal and subtidal zones, common on rocky surfaces

DISTRIBUTION Temperate waters of northeast and northwest Pacific

Chitons are mollusks with shells made up of eight arching and overlapping plates. The lined chiton is so called because of a series of zigzagging blue or red lines on its shell. The shell is usually pinkish in color, which provides good camouflage as this chiton grazes from rocks that are covered with encrusting pink coralline algae. The lined chiton's mantle extends around the shell on all sides, forming an unusually smooth, leathery "girdle" that helps to hold its eight shell-plates together. It has a large, muscular foot, which it uses to move over rocks and, when still, to grip on to them in much the same way as limpets do. At low tide, it remains stationary to avoid water loss. Its head is small and eyeless. The sexes are separate and it reproduces by releasing its gametes into the water.