activity can look like heat lightning rippling through a cloudy summer night. Whatever the motivation for contact flashing among simpler organisms, more highly developed animals of the midwater region seem well adapted to the situation.

Midwater Attackers

Fish such as hake, as well as some squids, are fast-moving, wide-ranging predators, but they often linger near *Ventana,* attracted to the lights of the ROV. It may be that they misinterpret the illuminated waters as an indication that moving prey are present. Perhaps they are conditioned by the daily excursions of sunlight-shunning species that venture near the surface only at night. Such vertical migrations must be light-provoking events, as these animals pass through resident layers of contact flashers. But the potential for movement-induced bioluminescence probably inhibits overall activity, keeping the midwater environment relatively static. Avoiding unnecessary light shows that would give away their position may be the reason mobile animals seem often to remain "parked" in one position much of the time.

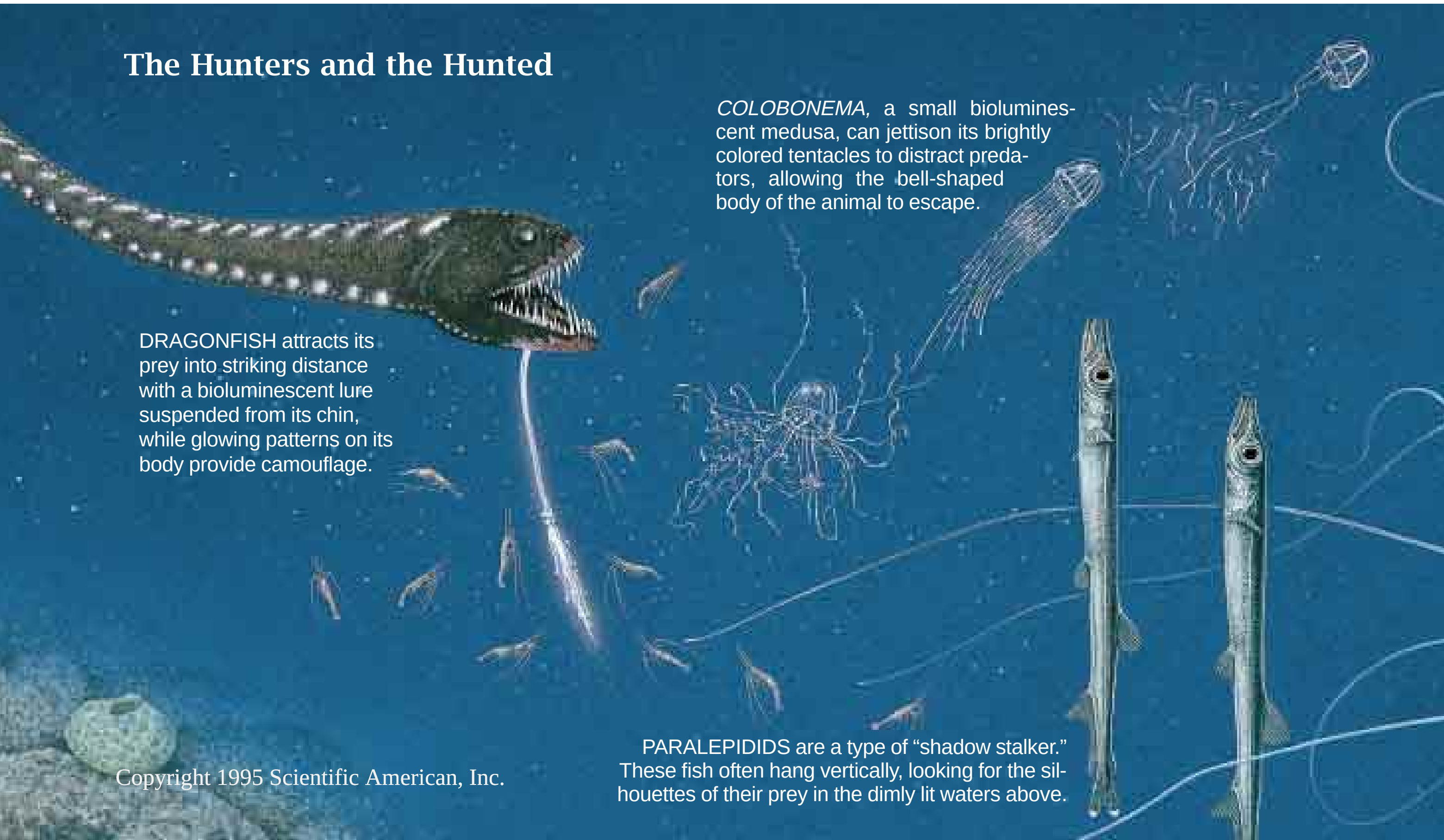
Even some predators stay largely motionless. For instance, paralepidids—slender, speedy fish with bodies that look as though they are made of quicksilver—spend the daylight hours standing on their tails, with their sharp snouts thrust upward and their large eyes staring into the waters above. My colleagues and I believe they are searching for silhouettes of their prey against the weakly luminous backdrop. The hatchetfish *Argyropelecus* is another shadow stalker; it has a heavy keel to keep its body horizontal and to stabilize a pair of tubular eyes positioned on top of its body so that its view remains directed upward. *Argyropelecus* lives between about 300 and 600 meters below the surface, where the sunlight must be sufficient to cast perceptible shadows. But a close relative, *Sternoptyx,* lives at depths too great to employ this tactic and has smaller, normally shaped eyes aimed out to the sides.

Further evidence indicates that the weak sunlight of the midwaters is strong enough to guide predators: a diversity of animals living at these depths are transparent. Such a form of appearance (or rather, disappearance) is good protection in this monochromatic, low-light environment. Another optical defense mechanism is red body pigment; this color absorbs the available blue-green light and reflects nothing, a kind of "visual stealth" strategy.

It is not surprising that such optical ploys can work effectively. The visual regime in the midwaters is a bit like the scene from a low-light video surveillance camera. The range of color is narrow; sensitivity is high, but resolution is low; and the directionality of light imparts a flatness to perceptions. To the unaided human eye, the visual field amounts to a coarse pattern of silhouettes and shadows. Within this light-limited milieu there appear to be only four basic shapes: streaks, blobs, strings and spots. Each of these phantoms characterizes a certain kind of subject. Streaks correspond to fishes and squids. Rounded or amorphous blobs are usually gelatinous creatures such as medusae and ctenophores or the weblike feeding structures built from mucus by appendicularians. Stringy material is typically sinking mucus or the tails of siphonophores. Spots can be tiny zooplankton or particles of diffuse organic matter called marine snow.

Within this framework we see a common behavior pattern employed by a variety of creatures. When startled or threatened, some animals change their apparent shape, usually from elongate to rounded. Fishes such as eelpouts curl up into circles and hang motionless in the water. I believe this behavior is a form of mimicry: the animals adjust their appearance to resemble unpalatable objects. From *Deep Rover* I have seen hake strike at fleeing fish while ignoring those that had curled up nearby. The balled-up fish probably resembled medusae—creatures of relatively low nutritional value that deter predators with stinging tentacles. Not all marine biologists agree with this hypothe-

The Hunters and the Hunted



COLOBONEMA, a small bioluminescent medusa, can jettison its brightly colored tentacles to distract predators, allowing the bell-shaped body of the animal to escape.

DRAGONFISH attracts its prey into striking distance with a bioluminescent lure suspended from its chin, while glowing patterns on its body provide camouflage.

PARALEPIDIDS are a type of "shadow stalker." These fish often hang vertically, looking for the silhouettes of their prey in the dimly lit waters above.

sis, but the observation that this behavior is rarely seen at greater depths (where there is insufficient light for the formation of even rough images) supports the argument for the utility of shape-changing. Such behavior has certainly fooled me at times.

Light for the Blind

Most gelatinous animals, such as medusae, lack eyes and thus cannot form images of any kind. Yet some of these creatures are clearly sensitive to the lights of *Ventana,* even at a distance, showing a mild dislike for the brightness. My colleagues and I are accumulating evidence that suggests this sensitivity to light may regulate the animal's depth during the day. Changing light levels are known to control the morning and evening migrations of fishes and krill, and it would now seem possible that even eyeless creatures may somehow perceive the sun's presence above them.

We documented one example of such light sensitivity during an encounter with an animal called *Bathyphysa.* This bizarre creature, which is about two meters long, has appeared in front of *Ventana*'s cameras only once, while the vehicle was cruising 500 meters below the surface. When the ROV approached it, the stem of the animal was vertical, with its gas-filled "pneumatophore" uppermost. The stem of the *Bathyphysa* had a mane of elongate, serial stomachs (so-called gastrozooids), each with a probing mouth at its end, and all were writhing like snakes. Several five- to 10-meter-long feeding tentacles radiated out from a round, contracted part of the stem at its center. The stem was exceptionally elastic, a trait that seemed to be explained when we discovered the animal's escape response. Sensing the lights of the ROV, this creature began a series of pounding contractions and relaxations of the upper stem that had the effect of driving the animal downward. In concert with these pulsations, gastrozooids were cast off and left to drift away, one at a time. The result was a determined descent, although a fairly slow and taxing one.

Such episodes suggest that eyeless creatures might well be able to sense even low-level light. In any case, it is clear that they can generate it. *Colobonema,* for example, is a beautifully iridescent little medusa that has a "bell" that is about the size of a coin. In the lights of the ROV, muscle bands in the bell have a blue-green metallic sheen. The medusa's tentacles show a deep blue along their length and brilliant white at the tips.

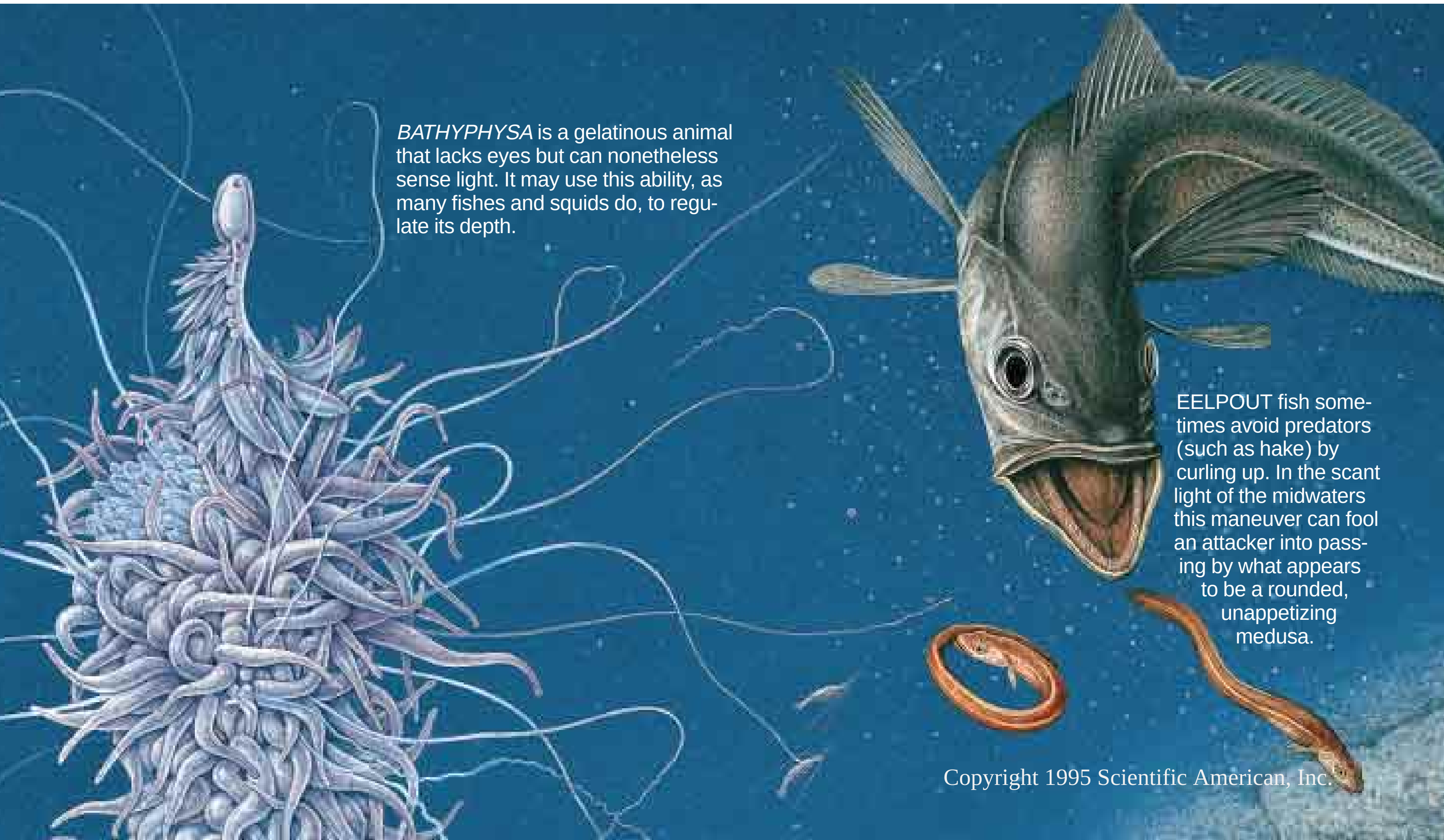
A fully developed individual has 32 tentacles arrayed uniformly around the base of the bell. Often, however, specimens show fewer appendages set in tiers of different lengths. This appearance is perhaps explained by the animal's behavior: when startled, *Colobonema* darts away, leaving a group of bright, swirling tentacles in its wake. From *Deep Rover* I have observed that the release is occasionally preceded by ripples of luminescence pulsing rapidly through the bell. The many tentacles are then dropped as the bell goes dark and zigzags away into the surrounding blackness.

Occupants of the Oxygen Minimum

One of the characteristic features of the Pacific Ocean near Monterey Bay is a zone that is depleted in dissolved oxygen. Just below the sea surface, oxygen concentrations are close to saturation (that is, the water holds as much oxygen as can possibly be dissolved), but deeper in the ocean, oxygen content diminishes. At about 700 meters of depth, oxygen concentration falls to a value that is only one thirtieth of that near the surface. Below this level is a sharp transition from relatively clear water to a milky layer of very small particles. The milky layer shows a moderate amount of oxygen, and at 1,000 meters the concentration rises further. Within the zone of lowest oxygen near 700 meters resides a unique group of animals that have adapted to meet the physiological challenges of near-anoxia.

One of the most curious inhabitants of the oxygen minimum is the archaic

ROBERTO OSTI



BATHYPHYSA is a gelatinous animal that lacks eyes but can nonetheless sense light. It may use this ability, as many fishes and squids do, to regulate its depth.

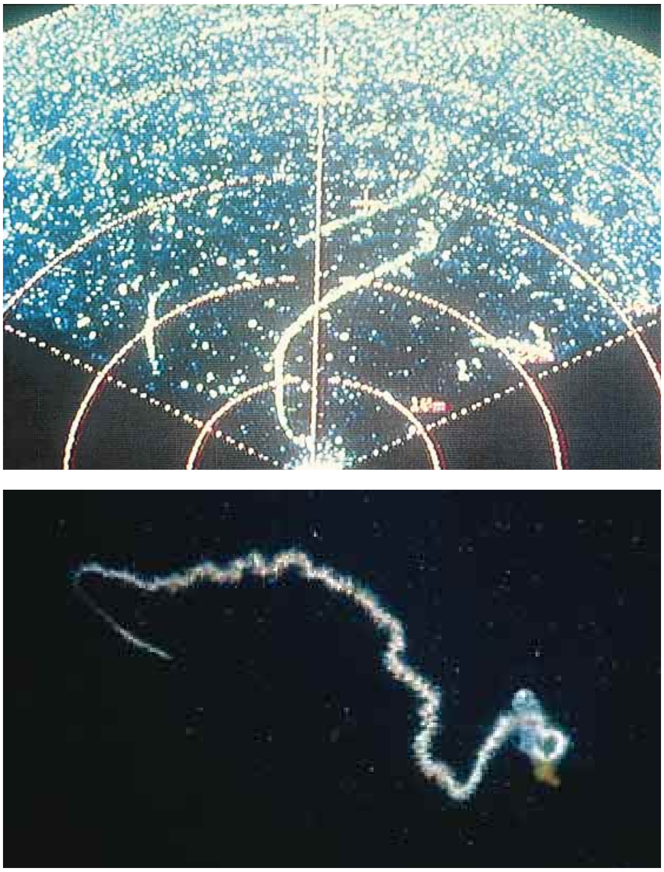
EELPOUT fish sometimes avoid predators (such as hake) by curling up. In the scant light of the midwaters this maneuver can fool an attacker into passing by what appears to be a rounded, unappetizing medusa.

cephalopod *Vampyroteuthis infernalis,* a distant cousin to octopus and squid. A big *Vampyroteuthis* has the size and shape of a soft football. Its body is velvety brown with large eyes that glow like blue opals in the ROV lights. Near the tip of the stubby, conical mantle are two rounded fins and two large light organs with irislike shutters. *Vampyroteuthis* has eight arms like an octopus, but they support a broad web between them. In addition to having suckers, the arms bear a series of paired, fingerlike protrusions, called cirri, that project inward. *Vampyroteuthis* also has two additional appendages: long, elastic sensory filaments that withdraw into pockets between the third and fourth arms on each side.

This creature can be regarded as a living fossil, a modern-day representative of the cephalopods that preceded the evolutionary split into eight- and 10-armed groups. *Vampyroteuthis* propels itself with jets of water expelled from its siphon and by flapping its stubby fins. At the center of the webbed arms is a dark, hooked beak. We do not yet know what this animal eats, but it substantially reduces its own chances of being consumed by living in an inhospitable, anoxic part of the ocean.

My colleagues and I have discovered that this strange animal has a bioluminescent organ at the tip of each of its arms. *Vampyroteuthis* somehow uses these light sources by swinging its webbed arms upward and over the mantle, which turns the suckers and cirri outward and changes the animal's likeness from a football into a spiky pineapple with a glowing top.

This maneuver covers the animal's eyes, but the webbing between tentacles is apparently thin enough for it to see through. We have observed this transformation frequently but remain at a loss to explain exactly what function this unusual behavior might serve.



MONTEREY BAY AQUARIUM RESEARCH INSTITUTE

***APOLEMIA,* an elongate gelatinous creature (*bottom*), may be regarded as either a colonial animal or a superorganism. A sonar scan of such "living drift nets" (*top*) has semicircular reference lines at 10-meter increments and shows that some of these organisms can extend up to 40 meters, making them among the longest animals known.**

Technology-Driven Exploration

The present length of *Ventana*'s umbilical tether has permitted us to explore a volume of water one kilometer deep with a visual resolution that extends from about one centimeter to several hundred meters. Although this span covers the ranges of a large portion of the region's midwater species, there are still many measurements we cannot yet make. But this situation is changing. Future technical development by engineers at our institute should allow us to probe even deeper. Soon new optical and acoustic sensing systems will let us examine larger volumes from greater distances and so allow us to assess the distribution of midwater animals even more thoroughly.

We expect eventually to have autonomous probes that will leave time-lapse cameras in place so that we can track slowly moving animals around the clock for days at a time. Fast-swimming robotic vehicles will follow mobile animals, allowing us better to observe their feeding and migration patterns. The possibilities for investigation seem endless. Hence, despite the numerous discoveries already made, we must consider our undersea investigations to have just begun—the ocean's depths are so vast, and there is so much more to explore.

The Author

BRUCE H. ROBISON developed his curiosity about the ocean early, growing up on the beach in southern California. After receiving a B.S. from Purdue University and an M.A. from the Virginia Institute of Marine Science, he returned to his home state to attend Stanford University, where he completed a Ph.D. degree in 1973. Robison then spent two years in postdoctoral training at the Woods Hole Oceanographic Institution in Massachusetts before taking a position at the University of California, Santa Barbara. In 1987 he joined the fledgling Monterey Bay Aquarium Research Institute in Pacific Grove, Calif., where he is currently a senior scientist and science department chair. Robison's research in deep-sea ecology has carried him throughout the Pacific, to the Atlantic and to the great Southern Ocean surrounding Antarctica. He led the first team of scientists trained as submersible pilots and has long been active in promoting advanced undersea vehicles for oceanographic research.

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