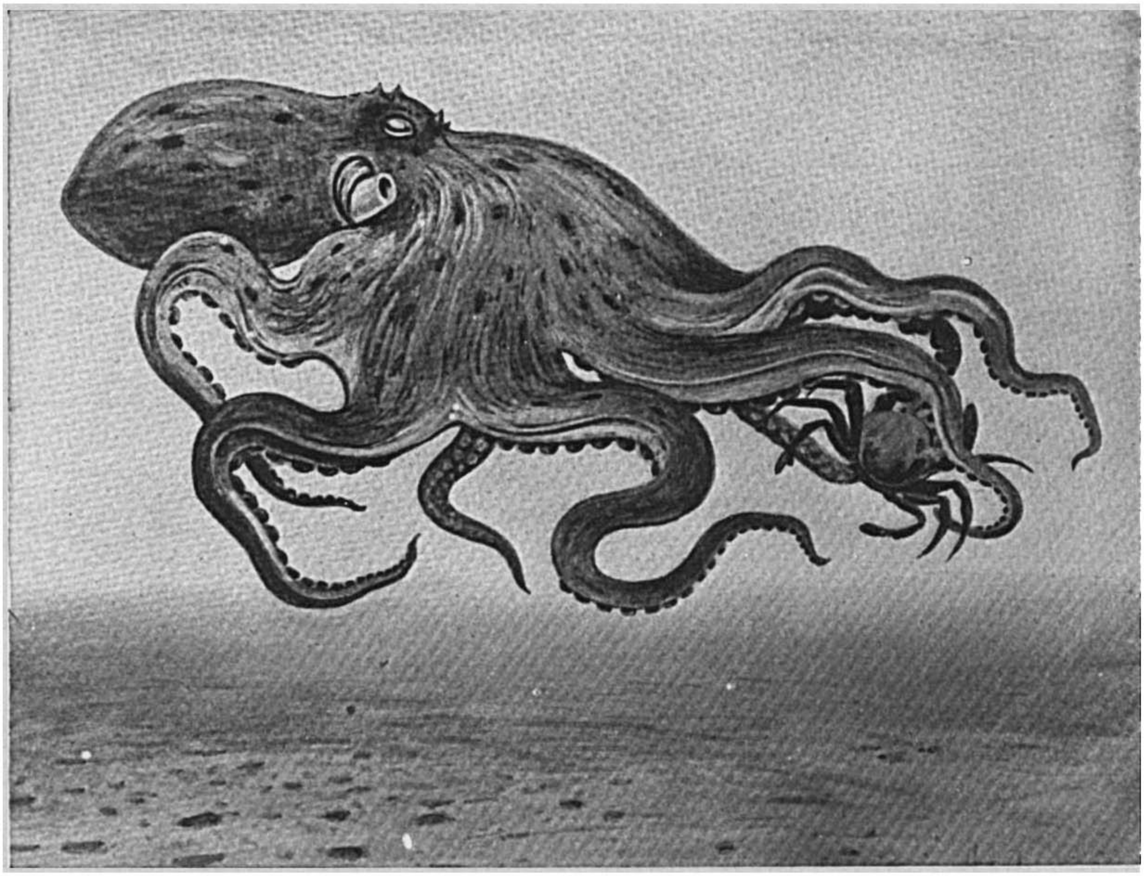
III

ADAPTATIONS TO ENVIRONMENT

WE saw in a previous chapter how the process of evolution led to a mastery of all the haunts of life. But it is necessary to return to these haunts or homes of animals in some detail, so as to understand the peculiar circumstances of each, and to see how in the course of ages of struggle all sorts of self-preserving and race-continuing adaptations or fitnesses have been wrought out and firmly established. Living creatures have spread over all the earth and in the waters under the earth; some of them have conquered the underground world and others the air. It is possible, however, as has been indicated, to distinguish six great haunts of life, each tenanted by a distinctive fauna, namely, the shore of the sea, the open sea, the depths of the sea, the fresh-waters, the dry land, and the air. In the deep sea there are no plants at all; in the air the only plants are floating bacteria, though there is a sense in which a tree is very aerial, and the orchid perched on its branches still more so; in the other four haunts there is a flora as well as a fauna—the two working into one another's hands in interesting and often subtle inter-relations—the subject of a separate study.

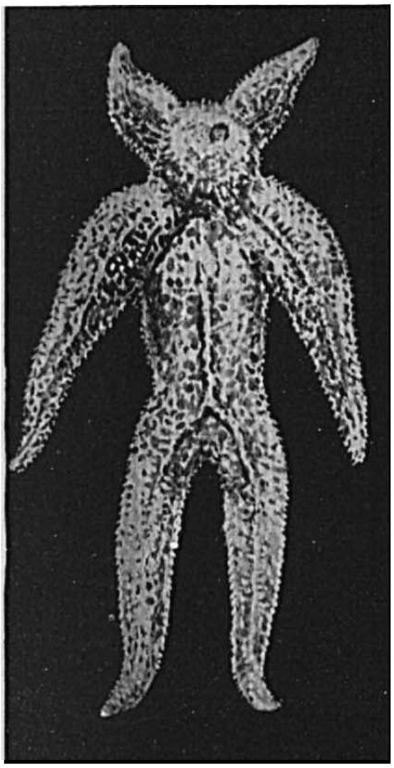


AN EIGHT-ARMED CUTTLEFISH OR OCTOPUS ATTACKING A SMALL CRAB.

These molluscs are particularly fond of crustaceans, which they crunch with their parrot's-beak-like jaws. Their salivary juice has a paralysing effect on their prey. To one side, below the eye, may be seen the funnel through which water is very forcibly ejected in the process of locomotion.

I. THE SHORE OF THE SEA

By the shore of the sea the zoologist means much more than the narrow zone between tide-marks; he means the whole of the relatively shallow, well-illumined, seaweed-growing shelf around the continents and continental islands. Technically, this is called the littoral area, and it is divisible into zones, each with its characteristic population. It may be noted that the green seaweeds are highest up on the shore; the brown ones come next; the beautiful red ones are lowest. All of them have got green chlorophyll, which enables them to utilise the sun's rays in photosynthesis (i.e. building up carbon compounds from air, water, and salts), but in the brown and red seaweeds the green pigment is masked by others. It is maintained by some botanists that these other pigments enable their possessors to make more of the scantier light in the deeper waters. However this may be, we must always think of the shore-haunt as the seaweed-growing area. Directly and indirectly the life of the shore animals is closely wrapped up with the seaweeds, which afford food and foothold, and temper the force of the waves. The minute fragments broken off from seaweeds and from the sea-grass (a flowering plant called Zostera) form a sort of nutritive sea-dust which is swept slowly down the slope from the shore, to form a very useful deposit in the quietness of deepish water. It is often found in the stomachs of marine animals living a long way offshore.



A COMMON STARFISH, WHICH HAS LOST THREE ARMS AND IS REGROWING THEM.
The lowest arm is being regrown double.
(After Professor W. C. McIntosh.)

The Sea-weed Area.

Conditions of Shore Life.

The littoral area as defined is not a large haunt of life; it occupies only about 9 million square miles, a small fraction of the 197,000,000 of the whole earth's surface. But it is a very long haunt, some 150,000 miles, winding in and out by bay and fiord, estuary and creek. Where deep water comes close to cliffs there may be no shore at all; in other places the relatively shallow water, with seaweeds growing over the bottom, may extend outwards for miles. The nature of the shore varies greatly according to the nature of the rocks, according to what the streams bring down from inland, and according to the jetsam that is brought in by the tides. The shore is a changeful place; there is, in the upper reaches, a striking difference between "tide in" and "tide out"; there are vicissitudes due to storms, to freshwater floods, to wind-blown sand, and to slow changes of level, up and down. The shore is a very crowded haunt, for it is comparatively narrow, and every niche among the rocks may be precious.

Keen Struggle for Existence.

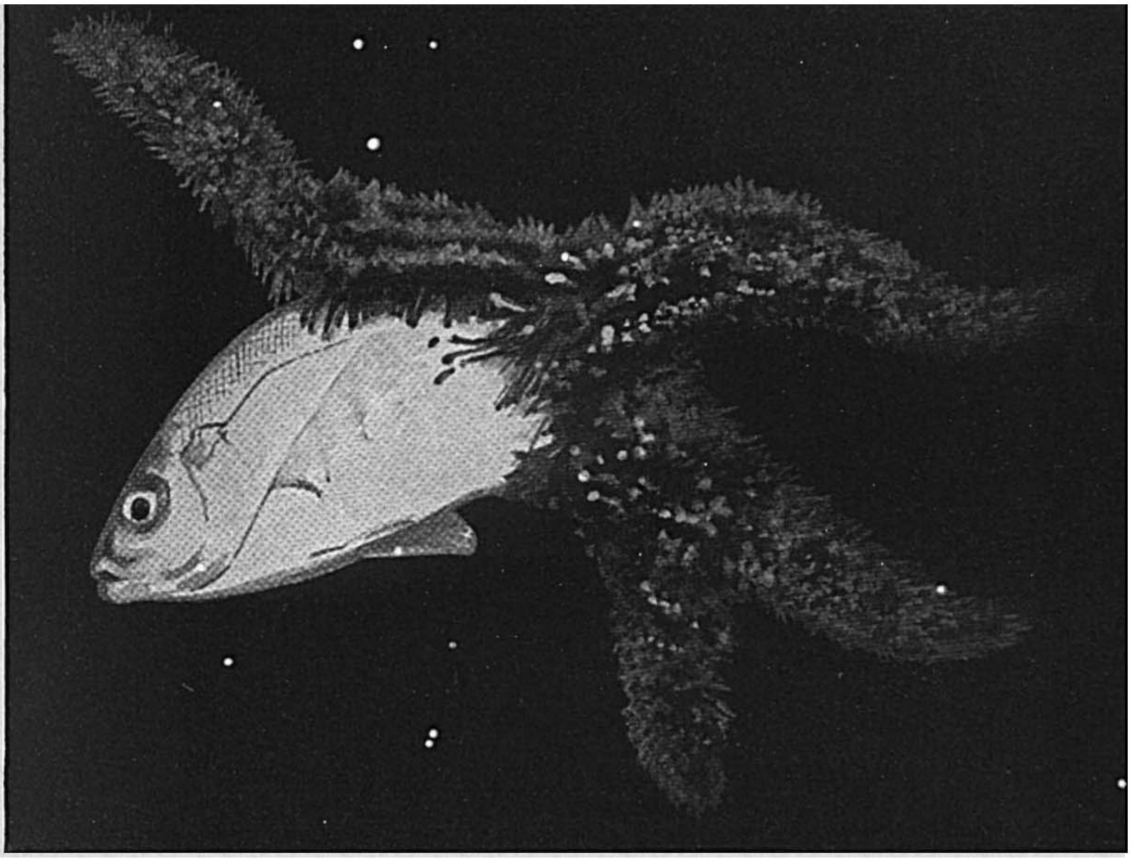
It follows that the shore must be the scene of a keen struggle for existence—which includes all the answers-back that living creatures make to environing difficulties and limitations. There is struggle for food, accentuated by the fact that small items tend to be swept away by the outgoing tide or to sink down the slope to deep water. Apart from direct competition, e.g. between hungry hermit-crabs, it often involves hard work to get a meal. This is true even of apparently sluggish creatures. Thus the Crumb-of-Bread Sponge, or any other seashore sponge, has to lash large quantities of water through the intricate canal system of its body before it can get a sufficient supply of the microscopic organisms and organic particles on which it feeds. An index of the intensity of the struggle for food is afforded by the nutritive chains which bind animals together. The shore is almost noisy with the conjugation of the verb to eat in its many tenses. One pound of rock-cod requires for its formation ten pounds of whelk; one pound of whelk requires ten pounds of sea-worms; and one pound of worms requires ten pounds of sea-dust. Such is the circulation of matter, ever passing from one embodiment or incarnation to another.

Besides struggle for food there is struggle for foothold and for fresh air, struggle against the scouring tide and against the pounding breakers. The risk of dislodgment is often great and the fracture of limbs is a common accident. Of kinds of armour—the sea-urchin's hedgehog-like test, the crab's shard, the limpet's shell—there is great variety, surpassed only by that of weapons—the sea-anemone's stinging-cells, the sea-urchin's snapping-blades, the hermit-crab's forceps, the grappling tentacles and parrot's-beak jaws of the octopus.

We get another glimpse of the intensity of the seashore struggle for existence in the frequency of "shifts for a living," adaptations of structure or of behaviour which meet frequently recurrent vicissitudes.

Shifts for a Living.

The starfish is often in the dilemma of losing a limb or its life; by a reflex action it jettisons the captured arm and escapes. And what is lost is gradually regrown. The crab gets its leg broken past all mending; it casts off the leg across a weak breakage plane near the base, and within a preformed bandage which prevents bleeding a new leg is formed in miniature. Such is the adaptive device—more reflex than reflective—which is called self-mutilation or autotomy.



A PHOTOGRAPH SHOWING A STARFISH (*ASTERIAS FORRERI*) WHICH HAS CAPTURED A LARGE FISH.
The suctorial tube-feet are seen gripping the fish firmly. (After an observation on the Californian coast.)

In another part of this book there is a discussion of camouflaging and protective resemblance; how abundantly these are illustrated on the shore! But there are other "shifts for a living." Some of the sand-hoppers and their relatives illustrate the puzzling phenomenon of "feigning death," becoming suddenly so motionless that they escape the eyes of their enemies. Cuttlefishes, by discharging sepia from their ink-bags, are able to throw dust in the eyes of their enemies. Some undisguised shore-animals, e.g. crabs, are adepts in a hide-and-seek game; some fishes, like the butterfish or gunnel, escape between stones where there seemed no opening and are almost uncatchable in their slipperiness. Subtlest of all, perhaps, is the habit some hermit-crabs have of entering into mutually beneficial partnership (commensalism) with sea-anemones, which mask their bearers and also serve as mounted batteries, getting transport as their reward and likewise crumbs from the frequently spread table. But enough has been said to show that the shore-haunt exhibits an extraordinary variety of shifts for a living.

According to Darwin, the struggle for existence, as a big fact in the economy of Animate Nature, includes not only competition but all the endeavours which secure the welfare of the offspring, and give them a good send-off in life. So it is without a jolt that we pass from struggle for food and foothold to parental care. The marine leech called Pontobdella, an interesting greenish warty creature fond of fixing itself to skate, places its egg-cocoons in the empty shell of a bivalve mollusc, and guards them for weeks, removing any mud that might injure their development. We have seen a British starfish with its fully-formed young ones creeping about on its body, though the usual mode of development for shore starfishes is that the young ones pass through a free-swimming larval period in the open water. The father sea-spider carries about the eggs attached to two of his limbs; the father sea-horse puts his mate's eggs into his breast pocket and carries them there in safety until they are hatched; the father stickleback of the

Parental Care on the Shore.

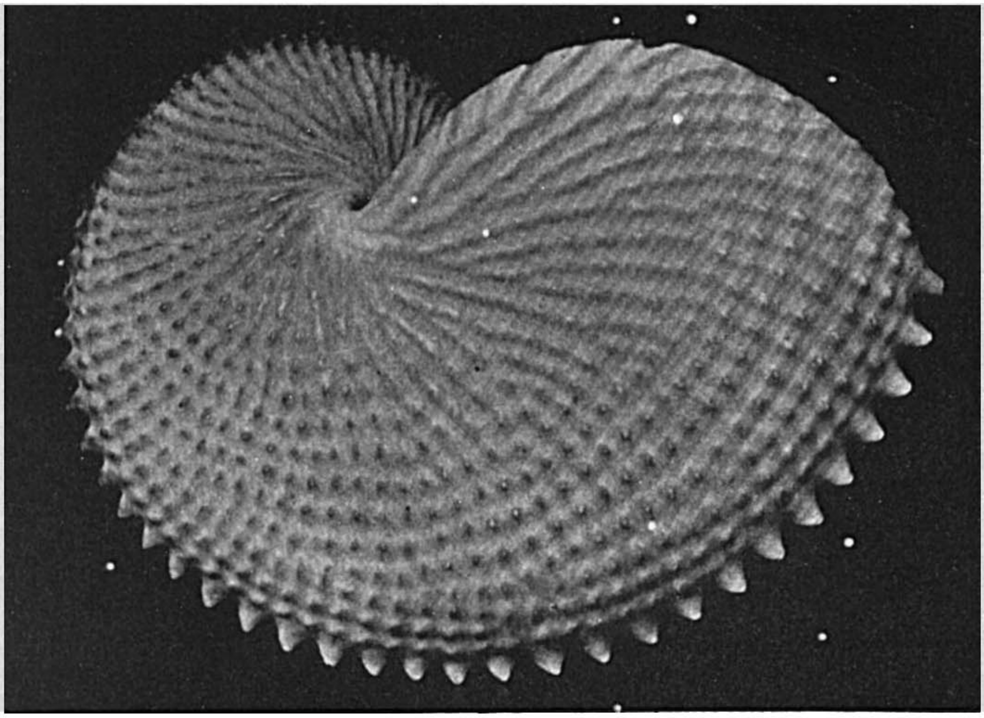
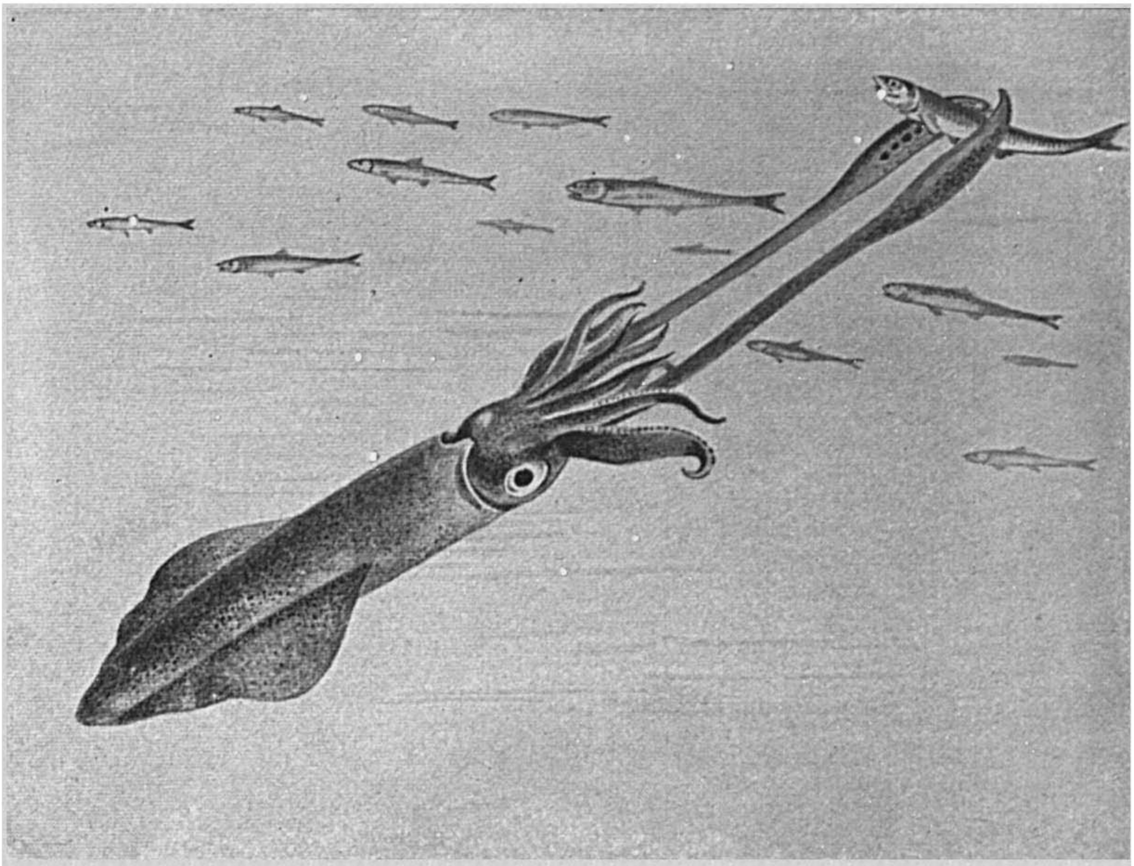


Photo: J. J. Ward, F.E.S.

THE PAPER NAUTILUS (ARGONAUTA), AN ANIMAL OF THE OPEN SEA.

The delicate shell is made by the female only, and is used as a shelter for the eggs and young ones. It is secreted by two of the arms, not by the mantle as other mollusc shells are. It is a single-chambered shell, very different from that of the Pearly Nautilus.



TEN-ARMED CUTTLEFISH OR SQUID IN THE ACT OF CAPTURING A FISH.

The arms bear numerous prehensile suckers, which grip the prey. In the mouth there are strong jaws shaped like a parrot's beak. The cuttlefishes are molluscs and may be regarded as the highest of the backboneless or Invertebrate animals. Many occur near shore, others in the open sea, and others in the great depths.

shore-pools makes a seaweed nest and guards the eggs which his wives are induced to lay there; the father lumpsucker mounts guard over the bunch of pinkish eggs which his mate has laid in a nook of a rocky shore-pool, and drives off intruders with zest. He also aerates the developing eggs by frequent paddling with his pectoral fins and tail, as the Scots name Cock-paidle probably suggests. It is interesting that the salient examples of parental care in the shore-haunt are mostly on the male parent's side. But there is maternal virtue as well.

The fauna of the shore is remarkably *representative*—from unicellular Protozoa to birds like the oyster-catcher and mammals like the seals. Almost all the great groups of animals have apparently served an apprenticeship in the shore-haunt, and since lessons learned for millions of years sink in and become organically enregistered, it is justifiable to look to the shore as a great school in which were gained racial qualities of endurance, patience, and alertness.

II. THE OPEN SEA

In great contrast to the narrow, crowded, difficult conditions of the shore-haunt (littoral area) are the spacious, bountiful, and relatively easygoing conditions of the open sea (pelagic area), which means the well-lighted surface waters quite away from land. Many small organisms have their maximum abundance at about fifty fathoms, so that the word "surface" is to be taken generously. The light becomes very dim at 250 fathoms, and the open sea, as a zoological haunt, stops with the light. It is hardly necessary to say that the pelagic plants are more abundant near the surface, and that below a certain depth the population consists almost exclusively of animals. Not a few of the animals sink and rise in the water periodically; there are some that come near the surface by day, and others that come near the surface by night. Of great interest is the habit of the extremely delicate Ctenophores or "sea-gooseberries," which the splash of a wave would tear into shreds. Whenever there is any hint of a storm they sink beyond its reach, and "the ocean's surface must have remained flat as a mirror for many hours before they can be lured upwards from the calm of their deep retreat."

MINUTE TRANSPARENT EARLY STAGE OF A SEA-CUCUMBER.

It swims in the open sea by means of girdles of microscopic cilia shown in the figure. After a period of free-swimming and a remarkable metamorphosis, the animal settles down on the floor of the sea in relatively shallow water.

The Floating Sea-meadows.

To understand the vital economy of the open sea, we must recognise the incalculable abundance of minute unicellular plants, for they form the fundamental food-supply. Along with these must also be included numerous microscopic animals which have got possession of chlorophyll, or have entered into internal partnership with unicellular Algæ (symbiosis). These green or greenish plants and animals are the *producers*, using the energy of the sunlight to help them in building up carbon compounds out of air, water, and salts. The animals which feed on the producers, or on other animals, are the *consumers*. Between the two come those open-sea bacteria that convert nitrogenous material, e.g. from dead plants or animals that other bacteria have rotted, into forms, e.g. nitrates, which plants can re-utilise. The importance of these *middlemen* is great in keeping "the circulation of matter" agoing.

The "floating sea-meadows," as Sir John Murray called them, are always receiving contributions from inshore waters, where the conditions are favourable for the prolific multiplication of unicellular Algæ, and there is also a certain amount of non-living sea-dust always

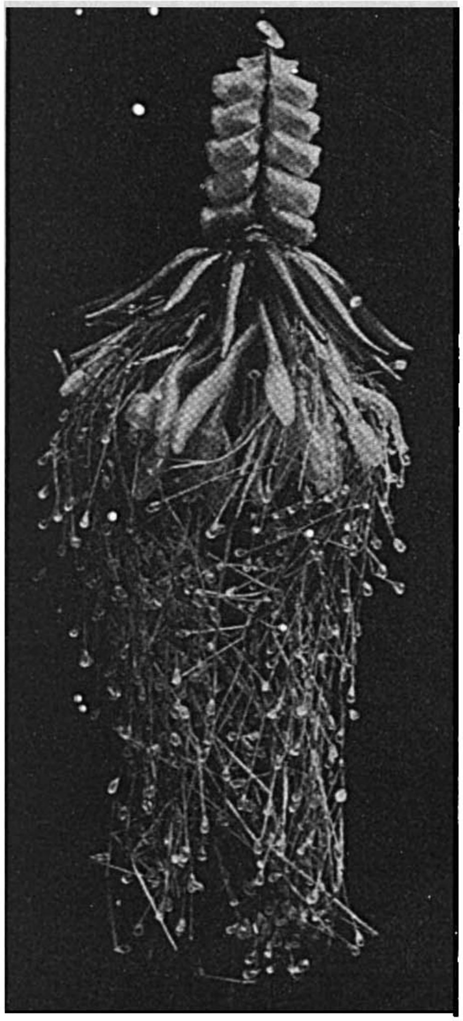


Photo: British Museum (Natural History).

AN INTRICATE COLONY OF OPEN-SEA ANIMALS (*PHYSOPHORA HYDROSTATICA*) RELATED TO THE PORTUGUESE MAN-OF-WAR.

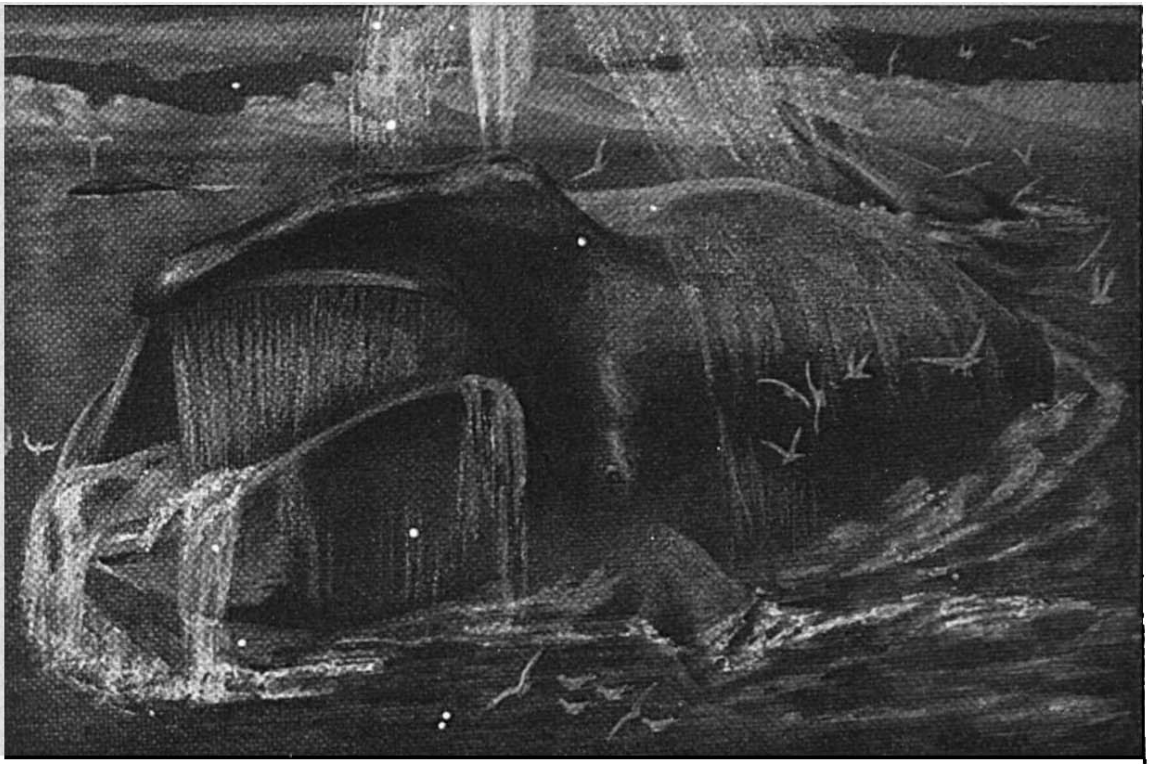
There is great division of labour in the colony. At the top are floating and swimming "persons"; the long ones below are offensive "persons" bearing batteries of stinging cells; in the middle zone there are nutritive, reproductive, and other "persons." The colour of the colony is a fine translucent blue. Swimmers and bathers are often badly stung by this strange animal and its relatives.

being swept out from the seaweed and sea-grass area.

The animals of the open sea are conveniently divided into the active swimmers (Nekton) and the more passive drifters (Plankton). The swimmers include whales great and small, such birds as the storm-petrel, the fish-eating turtles and sea-snakes, such fishes as mackerel and herring, the winged snails or sea-butterflies on which whalebone whales largely feed, some of the active cuttles or squids, various open-sea prawns and their relatives, some worms like the transparent arrow-worm, and such active Protozoa as Noctiluca, whose luminescence makes the waves sparkle in the short summer darkness. Very striking as an instance of the insurgence of life are the sea-skimmers (Halobatidæ), wingless insects related to the water-measurers in the ditch. They are found hundreds of miles from land, skimming on the surface of the open sea, and diving in stormy weather. They feed on floating dead animals.

Swimmers and Drifters.

The drifters or easygoing swimmers—for there is no hard and fast line—are represented, for instance, by the flinty-shelled Radiolarians and certain of the chalk-forming animals (Globigerinid Foraminifera); by jellyfishes, swimming-bells, and Portuguese men-of-war; by the comb-bearers or Ctenophores; by legions of minute Crustaceans; by strange animals called Salps, related to the sedentary sea-squirts; and by some sluggish fishes like globe-fishes, which often float idly on the surface.



GREENLAND WHALE.

Showing the double blowhole or nostrils on the top of the head and the whalebone plates hanging down from the roof of the mouth.

Open-sea animals tend to be delicately built, with a specific gravity near that of the sea-water, with adaptations, such as projecting filaments, which help flotation, and with capacities of rising and sinking according to the surrounding conditions. Many of them are luminescent, and many of them are very inconspicuous in the water owing to their transparency or their bluish colour. In both cases the significance is obscure.

Hunger is often very much in evidence in

A SCENE IN THE GREAT DEPTHS.

Showing a deep-sea fish of large gape, two feather-stars on the end of long stalks, a "sea-spider" (or Pycnogon) walking on lanky legs on the treacherous ooze, likewise a brittle-star, and some deep-sea corals.

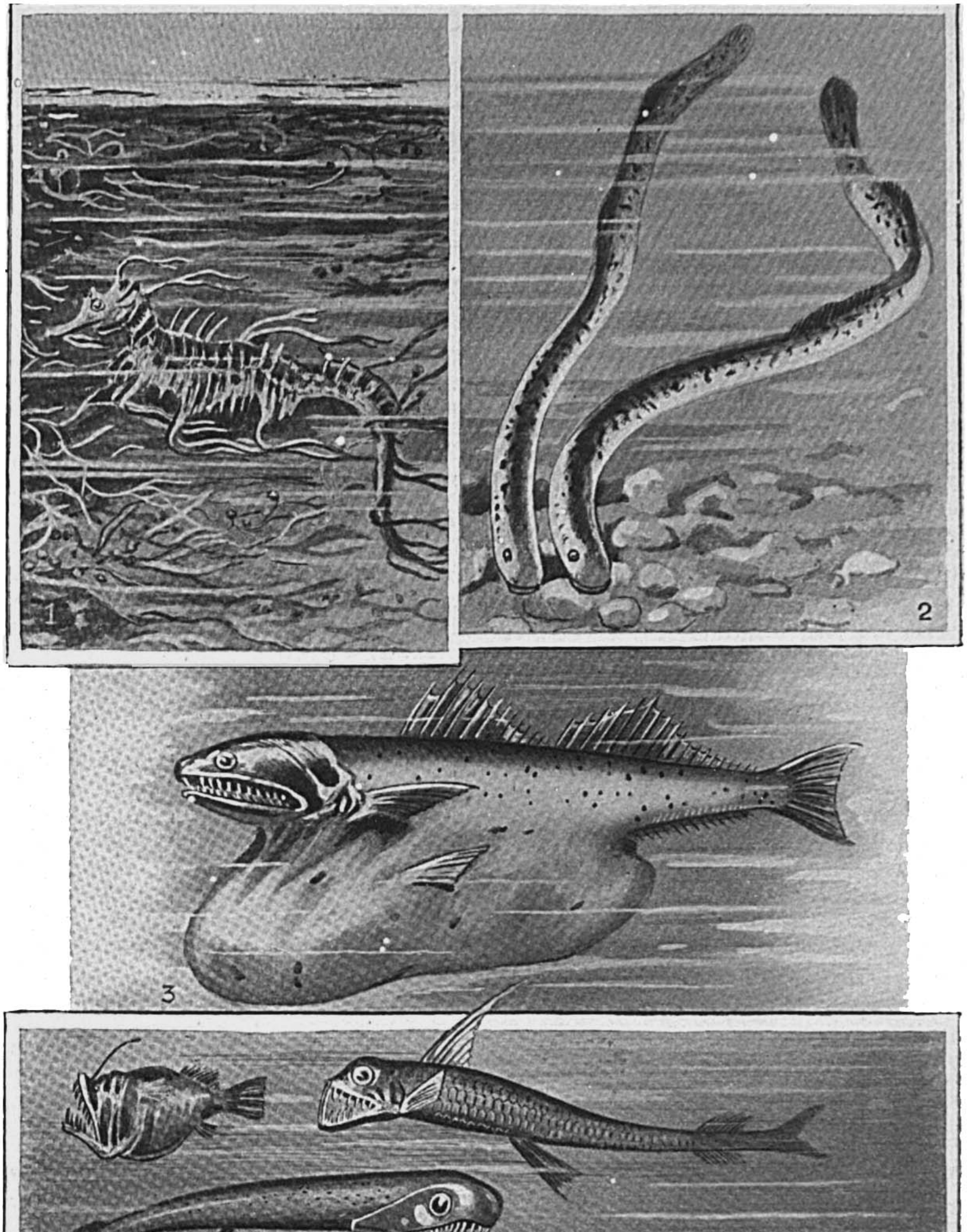
the open sea, especially in areas where the Plankton is poor. For there is great diversity in this respect, most of the Mediterranean, for instance, having a scanty Plankton as compared with the North Sea. In the South Pacific, west of Patagonia, there is said to be an immense "sea-desert" where there is little Plankton, and therefore little in the way of fishes. The success of fisheries in the North, e.g. on the Atlantic cod-banks, is due to the richness of the floating sea-meadows and the abundance of the smaller constituents of the animal Plankton.

Hunger and Love.

Hunger is plain enough when the Baleen Whale rushes through the water with open jaws, engulfing in the huge cavern of its mouth, where the pendent whalebone plates form a huge sieve, incalculable millions of small fry.

But there is love as well as hunger in the open sea. The maternal care exhibited by the whale reaches a very high level, and the delicate shell of the female Paper Nautilus or Argonaut, in which the eggs and the young ones are sheltered, may well be described as "the most beautiful cradle in the world."

Besides the permanent inhabitants of the open sea, there are the larval stages of many shore-animals which are there only for a short time. For there is an interesting give and take between the shore-haunt and the open sea. From the shore come nutritive contributions and minute organisms which multiply quickly in the open waters. But not less important is the fact that the open waters afford a safe cradle or nursery for many a delicate larva, e.g. of crab and starfish, acorn-shell and sea-urchin, which could not survive for a day in the rough-and-tumble conditions of the shore and the shallow water. After undergoing radical changes and gaining strength, the young creatures return to the shore in various ways.



1. SEA-HORSE IN SARGASSO WEED. In its frond-like tags of skin and in its colouring this kind of sea-horse is well concealed among the floating seaweed of the so-called Sargasso Sea.

2. THE LARGE MARINE LAMPREYS (*PETROMYZON MARINUS*), WHICH MAY BE AS LONG AS ONE'S ARM, SPAWN IN FRESH WATER. Stones and pebbles, gripped in the suctorial mouth, are removed from a selected spot and piled around the circumference, so that the eggs, which are laid within the circle, are not easily washed away.

3. THE DEEP-SEA FISH *CHIASMODON NIGER* IS FAMOUS FOR ITS VORACITY. It sometimes manages to swallow a fish larger than itself, which causes an extraordinary protrusion of the stomach.

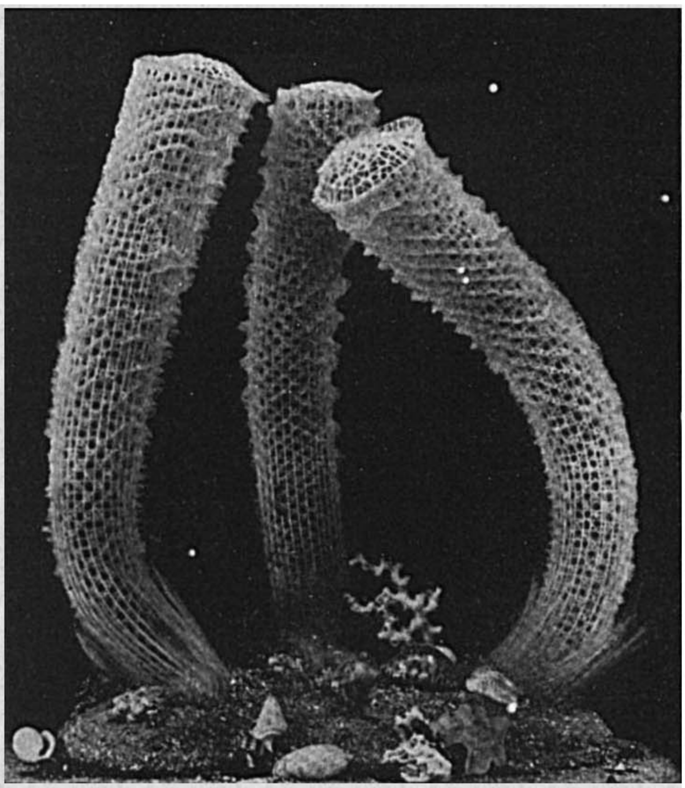
4. DEEP-SEA FISHES. Two of them—*Melanocetus murrayi* and *Melanocetus indicus*—are related to the Angler of British coasts, but adapted to life in the great abysses. They are very dark in colour, and delicately built; they possess well-developed luminous organs. The third form is called Chauliodus, a predatory animal with large gape and formidable teeth.

III. THE DEEP SEA

Very different from all the other haunts are the depths of the sea, including the floor of the abysses and the zones of water near the bottom. This haunt, forever unseen, occupies more than a third of the earth's surface, and it is thickly peopled. It came into emphatic notice in connection with the mending of telegraph cables, but the results of the *Challenger* expedition (1873–6) gave the first impressive picture of what was practically a new world.

Physical Conditions. The average depth of the ocean is about two and a half miles; therefore, since many parts are relatively shallow, there must be enormous depths. A few of these, technically called "deeps," are about six miles deep, in which Mount Everest would be engulfed. There is enormous pressure in such depths; even at 2,500 fathoms it is two and a half tons on the square inch. The temperature is on and off the freezing-point of fresh water (28°–34° Fahr.), due to the continual sinking down of cold water from the Poles, especially from the South. Apart from the fitful gleams of luminescent animals, there is utter darkness in the deep waters. The rays of sunlight are practically extinguished at 250 fathoms, though very sensitive bromo-gelatine plates exposed at 500 fathoms have shown faint indications even at that depth. It is a world of absolute calm and silence, and there is no scenery on the floor. A deep, cold, dark, silent, monotonous world!

Biological Conditions. While some parts of the floor of the abysses are more thickly peopled than others, there is no depth limit to the distribution of life. Wherever the long arm of the dredge has reached, animals have been found, e.g. Protozoa, sponges, corals, worms, starfishes, sea-urchins, sea-lilies, crustaceans, lamp-shells, molluscs, ascidians, and fishes—a very representative fauna. In the absence of light there can be no chlorophyll-possessing plants, and as the animals cannot all be eating one another there must be an extraneous source of food-supply. This is found in the sinking down of minute organisms which are killed on the surface by changes of temperature and other causes. What is left of them, before or after being swallowed, and of sea-dust and mineral particles of various kinds forms the diversified "ooze" of the sea-floor, a soft muddy precipitate, which is said to have in places the consistence of butter in summer weather.



FLINTY SKELETON OF VENUS FLOWER BASKET (EUPLECTELLA), A JAPANESE DEEP-SEA SPONGE.

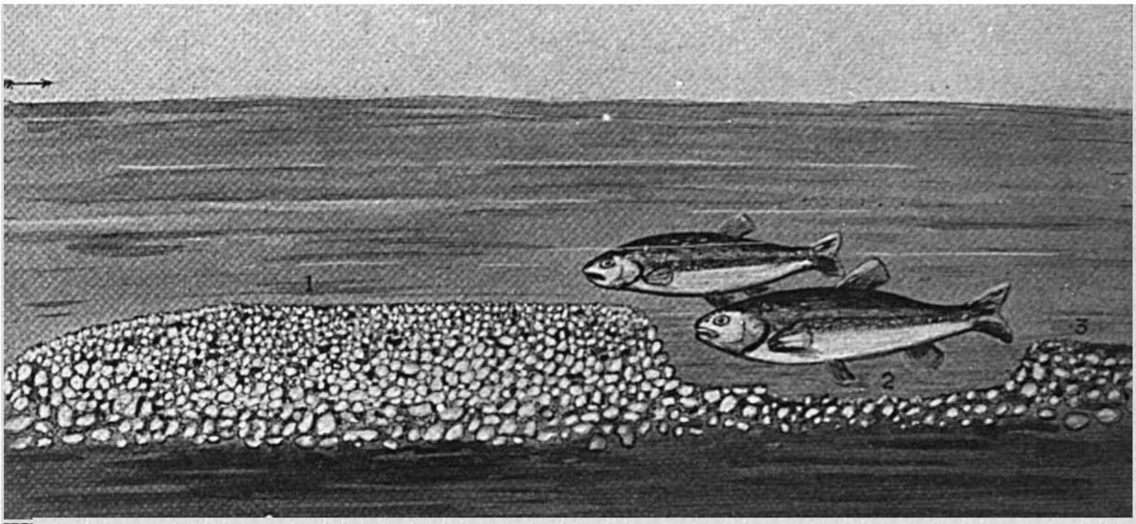
There seem to be no bacteria in the abysses, so there can be no rotting. Everything that sinks down, even the huge carcase of a whale, must be nibbled away by hungry animals and digested, or else, in the case of most bones, slowly dissolved away. Of the whale there are left only the ear-bones, of the shark his teeth.

In adaptation to the great pressure the bodies of deep-sea animals are usually very permeable,

Adaptations to Deep-sea Life.

so that the water gets through and through them, as in the case of Venus' Flower Basket, a flinty sponge which a child's finger would shiver. But when the pressure inside is the same as that outside nothing happens. In adaptation to the treacherous ooze, so apt to smother, many of the active deep-sea animals have very long, stilt-like legs, and many of the sedentary types are lifted into safety on the end of long stalks which have their bases embedded in the mud. In adaptation to the darkness, in which there is only luminescence that eyes could use, there is a great development of tactility. The interesting problem of luminescence will be discussed elsewhere.

As to the origin of the deep-sea fauna, there seems no doubt that it has arisen by many contributions from the various shore-haunts. Following the down-drifting food, many shore-animals have in the course of many generations reached the world of eternal night and winter, and become adapted to its strange conditions. For the animals of the deep-sea are as fit, beautiful, and vigorous as those elsewhere. There are no slums in Nature.



EGG DEPOSITORY OF *SEMOTILUS ATROMACULATUS*.

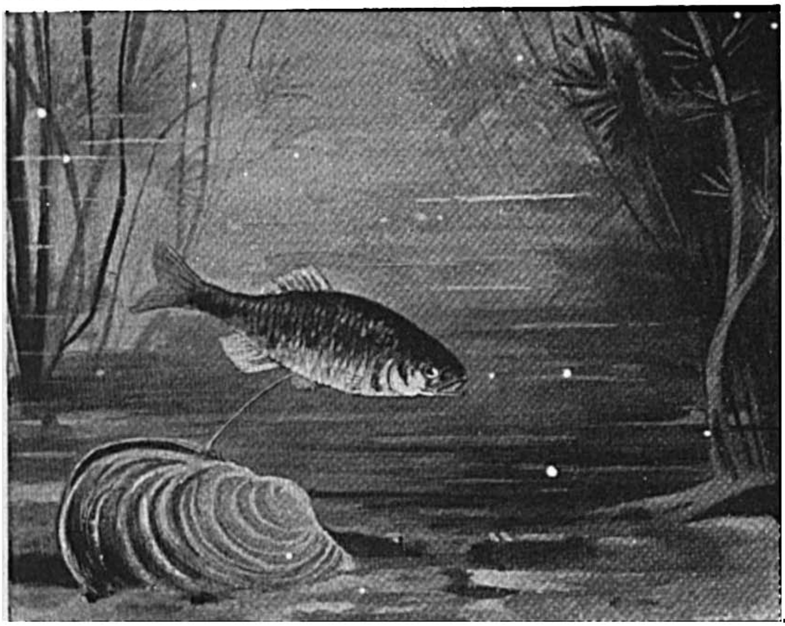
In the building of this egg depository, the male fish taker stones from the bottom of the stream, gripping them in his mouth, and heaps them up into the dam. In the egg depository he arranges the stones so that when the eggs are deposited in the interstices they are thoroughly protected and cannot be washed down-stream.

1, dam of stones; 2, egg depository; 3, hillock of sand. The arrow shows the direction of the stream. Upper fish, male; lower, female.

IV. THE FRESHWATERS

Of the whole earth's surface the freshwaters form a very small fraction, about a hundredth, but they make up for their smallness by their variety. We think of deep lake and shallow pond, of the great river and the purling brook, of lagoon and swamp, and more besides. There is a striking resemblance in the animal population of widely separated freshwater basins: and this is partly because birds carry many small creatures on their muddy feet from one watershed to another; partly because some of the freshwater animals are descended from types which made their way from the sea and the seashore through estuaries and marshes, and only certain kinds of constitution could survive the migration; and partly because some lakes are landlocked dwindling relics of ancient seas, and similar forms again would survive the change.

A typical assemblage of freshwater animals would include many Protozoa, like Amœbæ and the Bell-Animalcules, a representative of one family of sponges (Spongillidæ), the common Hydra, many unsegmented worms (notably Planarians and Nematodes), many Annelids related to the earthworms, many crustaceans,



THE BITTERLING (*RHODEUS AMARUS*).
A Continental fish which lays its eggs by means of a long ovipositor inside the freshwater mussel. The eggs develop inside the mollusc's gill-plates.

insects, and mites, many bivalves and snails, various fishes, a newt or two, perhaps a little mud-turtle or in warm countries a huge Crocodilian, various interesting birds like the water-ouzel or dipper, and mammals like the water-vole and the water-shrew.

Freshwater animals have to face certain difficulties, the greatest of which are drought, frost, and being washed away in times of flood. There is no more interesting study in the world than an inquiry into the adaptations by which freshwater animals overcome the difficulties of the situation. We cannot give more than a few illustrations.

(1) Drought is circumvented by the capacity that many freshwater animals have of lying low and saying nothing. Thus the African mudfish may spend half the year encased in the mud, and many minute crustaceans can survive being dried up for years. (2) Escape from the danger of being frozen hard in the pool is largely due to the almost unique property of water that it expands as it approaches the freezing-point. Thus the colder water rises to the surface and forms or adds to the protecting blanket of ice. The warmer water remains unfrozen at the bottom, and the animals live on. (3) The risk of being washed away, e.g. to the sea, is lessened by all sorts of gripping, grappling, and anchoring structures, and by shortening the juvenile stages when the risks are greatest.

V. THE DRY LAND

Over and over again in the history of animal life there have been attempts to get out of the water on to terra firma, and many of these have been successful, notably those made (1) by worms, (2) by air-breathing Arthropods, and (3) by amphibians.

In thinking of the conquest of the dry land by animals, we must recognise the indispensable rôle of plants in preparing the way. The dry ground would have proved too inhospitable had not terrestrial plants begun to establish themselves, affording food, shelter, and humidity. There had to be plants before there could be earthworms, which feed on decaying leaves and the like, but how soon was the debt repaid when the earthworms began their worldwide task of forming vegetable mould, opening up the earth with their burrows, circulating the soil by means of their castings, and bruising the particles in their gizzard—certainly the most important mill in the world.

Another important idea is that littoral haunts, both on the seashore and in the freshwaters, afforded the necessary apprenticeship and transitional experience for the more strenuous life on dry land. Much that was perfected on land had its beginnings on the shore. Let us inquire, however, what the passage from water to dry land actually implied. This has been briefly discussed in a previous article (on Evolution), but the subject is one of great interest and importance.

Difficulties and Results of the Transition from Water to Land.

Leaving the water for dry land implied a loss in freedom of movement, for the terrestrial animal is primarily restricted to the surface of the earth. Thus it became essential that movements should be very rapid and very precise, needs with which we may associate the acquisition of fine cross-striped, quickly contracting muscles, and also, in time, their multiplication into very numerous separate engines. We exercise fifty-four muscles in the half-second that elapses between raising the heel of our foot in walking and planting it firmly on the ground again. Moreover, the need for rapid precisely controlled movements implied an improved nervous system, for the brain was a movement-controlling organ for ages before it did much in the way of thinking. The transition to terra firma also involved a greater compactness of body, so that there should not be too great friction on the surface. An animal like the jellyfish is unthinkable on land, and the elongated bodies of some land animals like centipedes and snakes are specially adapted so that they do not "sprawl." They are exceptions that prove the rule.

Getting on to dry land meant entering a kingdom where the differences between day and night, between summer and winter are more felt than in the sea. This made it advantageous to have protections against evaporation and loss of heat and other such dangers. Hence a variety of ways in which the surface of the body acquired a thickened skin, or a dead cuticle, or a shell, or a growth of hair, and so forth. In many cases there is an increase of the protection before the winter sets in, e.g. by

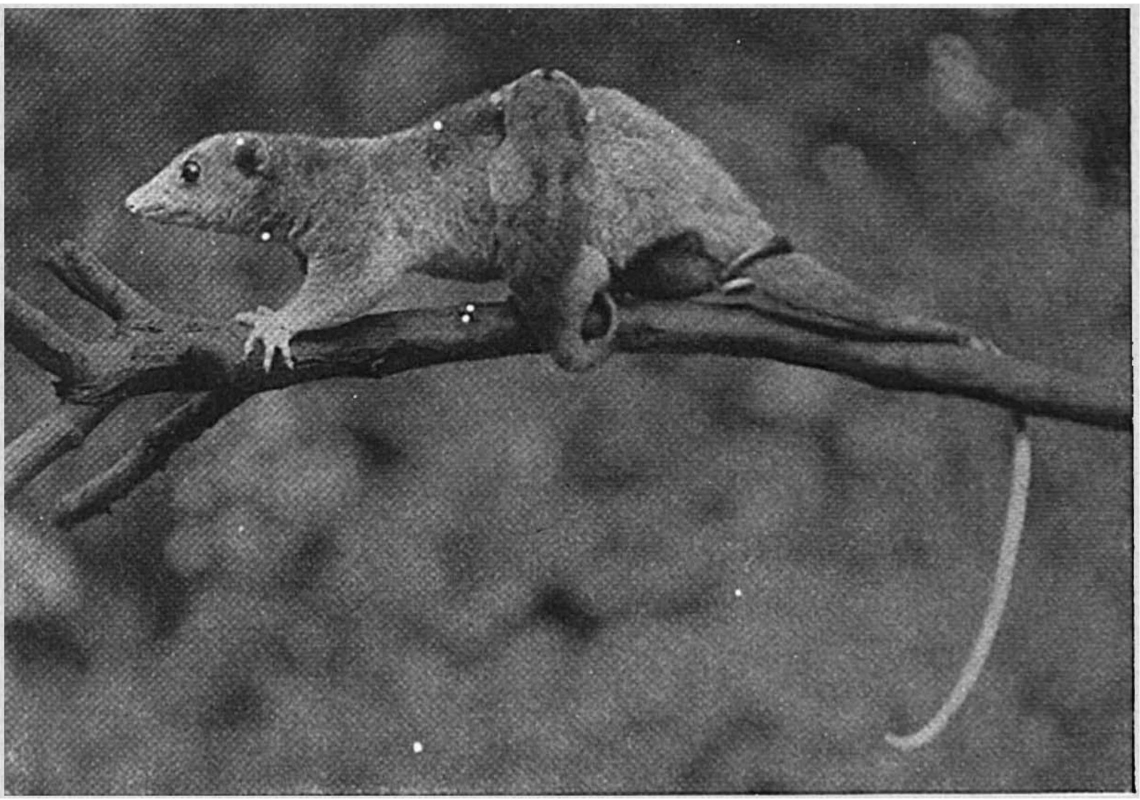


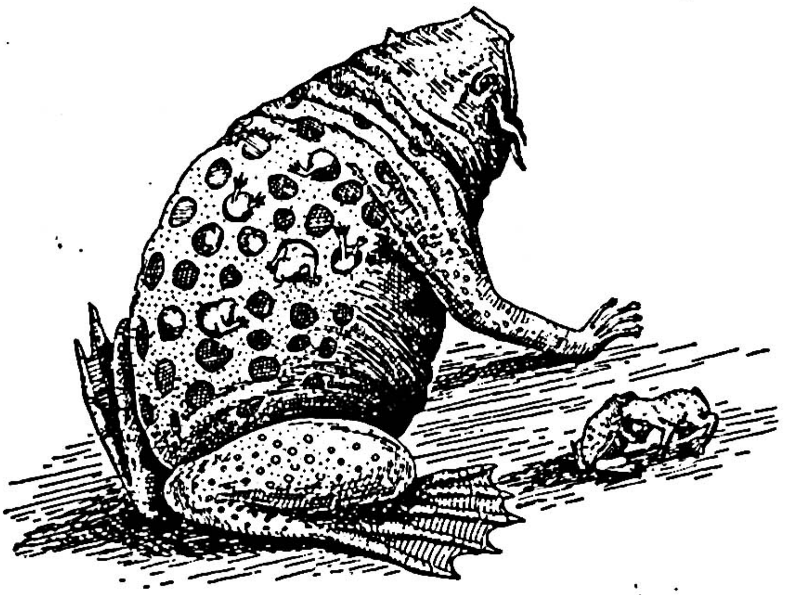
Photo: W. S. Berridge.

WOOLLY OPOSSUM CARRYING HER FAMILY.

One of the young ones is clinging to its mother and has its long prehensile tail coiled round hers.

growing thicker fur or by accumulating a layer of fat below the skin.

But the thickening or protection of the skin involved a partial or total loss of the skin as a respiratory surface. There is more oxygen available on dry land than in the water, but it is not so readily captured. Thus we see the importance of moist internal surfaces for capturing the oxygen which has been drawn into the interior of the body into some sort of lung. A unique solution was offered by Tracheate Arthropods, such as Peripatus, Centipedes, Millipedes, and Insects, where the air is carried to every hole and corner of the body by a ramifying system of air-tubes or tracheæ. In most animals the blood goes to the air, in insects the air goes to the blood. In the Robber-Crab, which has migrated from the shore inland, the dry air is absorbed by vascular tufts growing under the shelter of the gill-cover.



SURINAM TOAD (*PIPA AMERICANA*) WITH YOUNG ONES HATCHING OUT OF LITTLE POCKETS ON HER BACK.

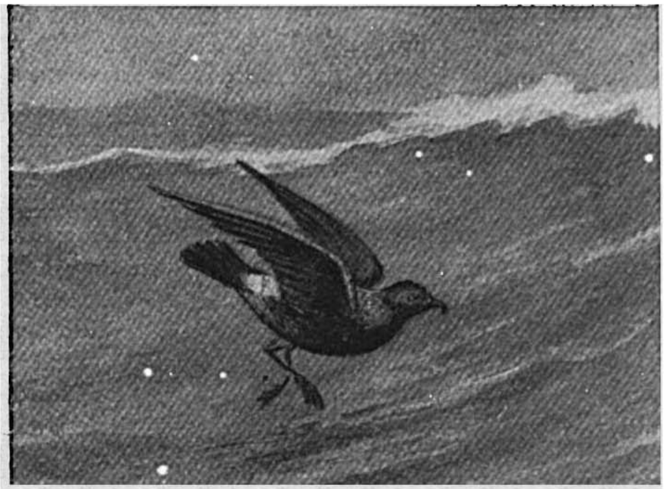
The problem of disposing of eggs or young ones is obviously much more difficult on land than in the water. For the water offers an immediate cradle, whereas on the dry land there were many dangers, e.g. of drought, extremes of temperature, and hungry sharp-eyed enemies, which had to be circumvented. So we find all manner of ways in which land animals hide their eggs or their young ones in holes and nests, on herbs and on trees. Some carry their young ones about after they are born, like the Surinam toad and the kangaroo, while others have prolonged the period of ante-natal life during which the young ones develop in safety within their mother, and in very intimate partnership with her in the case of the placental mammals. It is very interesting to find that the pioneer animal called Peripatus, which bridges the gap between worms and insects, carries its young for almost a year before birth.

Enough has been said to show that the successive conquests of the dry land had great evolutionary results. It is hardly too much to say that the invasion which the Amphibians led was the beginning of better brains, more controlled activities, and higher expressions of family life.

VI. THE AIR

There are no animals thoroughly aerial, but many insects spend much of their adult life in the free air, and the swift hardly pauses in its flight from dawn to dusk of the long summer day, alighting only for brief moments at the nest to deliver insects to the young. All the active life of bats certainly deserves to be called aerial.

The air was the last haunt of life to be conquered, and it is interesting to inquire what the conquest implied. (1) It meant transcending the radical difficulty of terrestrial life which confines the creatures of the dry land to moving on one plane, the surface of the earth. But the power of flight brought its possessors back to the universal freedom of movement which water animals enjoy. When we watch a sparrow rise into the air just as the cat has completed her stealthy stalking, we see that flight implies an enormous increase of safety. (2)



STORM PETREL OR MOTHER CAREY'S CHICKEN (*PROCELLARIA PELAGICA*).

This characteristic bird of the open sea does not come to land at all except to nest. It is the smallest web-footed bird, about four inches long. The legs are long and often touch the water as the bird flies. The storm petrel is at home in the Atlantic, and often nests on islands off the west coast of Britain.

The power of flight also opened up new possibilities of following the prey, of exploring new territories, of prospecting for water. (3) Of great importance too was the practicability of placing the eggs and the young, perhaps in a nest, in some place inaccessible to most enemies. When one thinks of it, the rooks' nests swaying on the tree-tops express the climax of a brilliant experiment. (4) The crowning advantage was the possibility of migrating, of conquering time (by circumventing the arid summer and the severe winter) and of conquering space (by passing quickly from one country to another and sometimes almost girdling the globe). There are not many acquisitions that have meant more to their possessors than the power of flight. It was a key opening the doors of a new freedom.

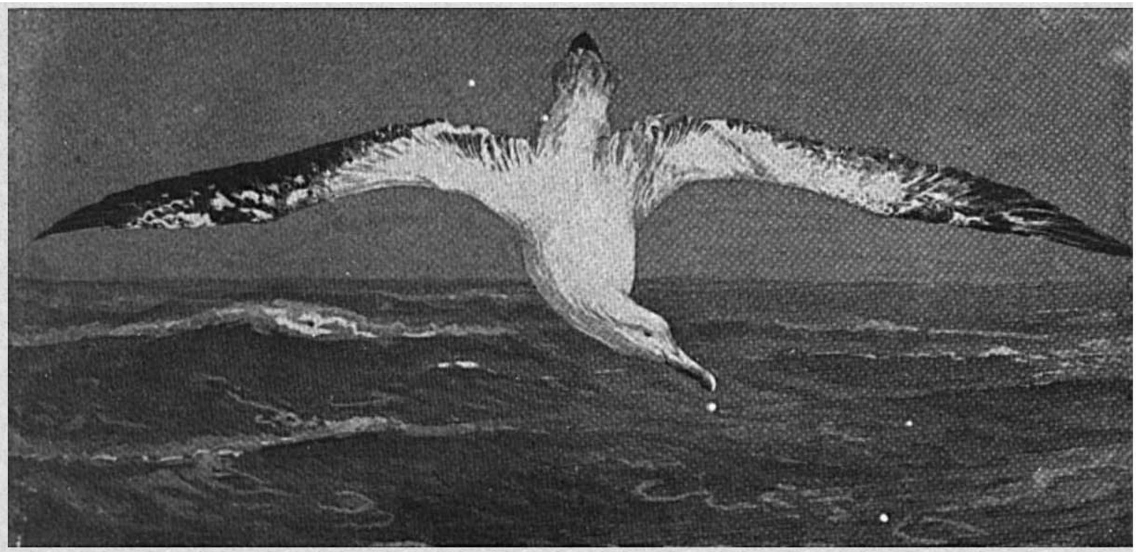
The problem of flight, as has been said in a previous chapter, has been solved four times, and the solution has been different in each case. The four solutions are those offered by insects, extinct Pterodactyls, birds, and bats. Moreover, as has been pointed out, there have been numerous attempts at flight which remain glorious failures, notably the flying fishes, which take a great leap and hold their pectoral fins taut; the Flying Tree-Toad, whose webbed fingers and toes form a parachute; the Flying Lizard (*Draco volans*), which has its skin pushed out on five or six greatly elongated mobile ribs; and various "flying" mammals, e.g. Flying Phalangers and Flying Squirrels, which take great swooping leaps from tree to tree.

The wings of an insect are hollow flattened sacs which grow out from the upper parts of the sides of the second and third rings of the region called the thorax. They are worked by powerful muscles, and are supported, like a fan, by ribs of chitin, which may be accompanied by air-tubes, blood-channels, and nerves. The insect's body is lightly built and very perfectly aerated, and the principle of the insect's flight is the extremely rapid striking of the air by means of the lightly built elastic wings. Many an insect has over two hundred strokes of its wings in one *second*. Hence, in many cases, the familiar hum, comparable on a small scale to that produced by the rapidly revolving blades of an aeroplane's propeller. For a short distance a bee can outfly a pigeon, but few insects can fly far, and they are easily blown away or blown back by the wind. Dragon-flies and bees may be cited as examples of insects that often fly for two or three miles. But this is exceptional, and the usual shortness of insect flight is an important fact for man since it limits the range of insects like house-flies and mosquitoes which are vehicles of typhoid fever and malaria respectively. The most primitive insects (spring-tails and bristle-tails) show no trace of wings, while fleas and lice have become secondarily wingless. It is interesting to notice that some insects only fly once in their lifetime, namely, in connection with mating. The evolution of the insect's wing remains quite obscure, but it is probable that insects could run, leap, and parachute before they could actually fly.

The extinct Flying Dragons or Pterodactyls had their golden age in the Cretaceous era, after which they disappeared, leaving no descendants. A fold of skin was spread out from the sides of the body by the enormously elongated outermost finger (usually regarded as corresponding to our little finger); it was continued to the hind-legs and thence to the tail.

It is unlikely that the Pterodactyls could fly far, for they have at most a weak keel on their breastbone; on the other hand, some of them show a marked fusion of dorsal vertebræ, which, as in flying birds, must have served as a firm fulcrum for the stroke of the wings. The quaint creatures varied from the size of a sparrow up to a magnificent spread of 15–20 feet from tip to tip of the wings. They were the largest of all flying creatures.

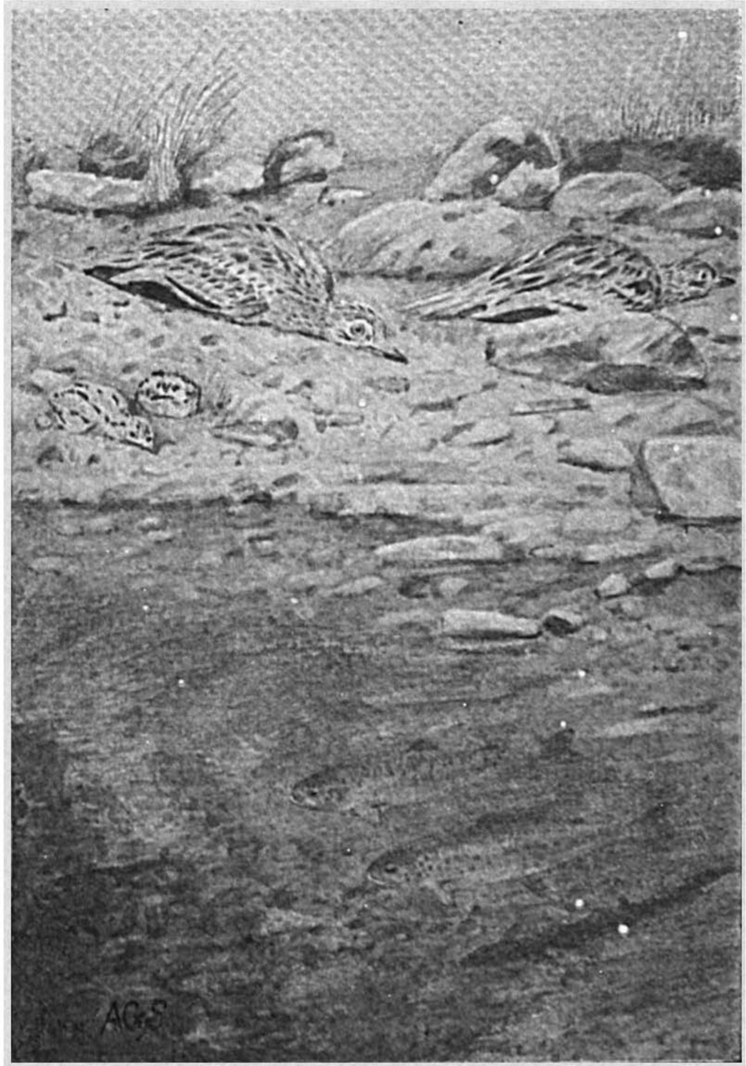
The bird's solution of the problem of flight, which will be discussed separately, is centred in the feather, which forms a coherent vane for striking the air. In Pterodactyl and bat the wing is a web-wing or patagium, and a small web is to be seen on the front side of the bird's wing. But the bird's patagium is unimportant, and the bird's wing is on an evolutionary tack of its own—a fore-limb transformed for bearing the feathers of flight. Feathers are in a general way comparable to the scales of reptiles, but only in a general way, and no transition stage is known between the two. Birds evolved from a bipedal Dinosaur stock, as has been noticed already, and it is highly probable that they began their ascent by taking running leaps along the ground, flapping their scaly fore-limbs, and balancing themselves in kangaroo-like fashion with an extended tail. A second chapter was probably an arboreal apprenticeship, during which they made a fine art of parachuting—a persistence of which is to be seen in the pigeon "gliding" from the dovecot to the ground. It is in birds that the mastery of the air reaches its climax, and the mysterious "sailing" of the albatross and the vulture is surely the most remarkable locomotor triumph that has ever been achieved. Without any apparent stroke of the wings, the bird sails for half an hour at a time with the wind and against the wind, around the ship and in majestic spirals in the sky, probably taking advantage of currents of air of different velocities, and continually changing energy of position into energy of motion as it sinks, and energy of motion into energy of position as it rises. It is interesting to know that some dragon-flies are also able to "sail."



ALBATROSS: A CHARACTERISTIC PELAGIC BIRD OF THE SOUTHERN SEA.

It may have a spread of wing of over 11 feet from tip to tip. It is famous for its extraordinary power of "sailing" round the ship without any apparent strokes of its wings.

The web-wing of bats involves much more than the fore-arm. The double fold of skin begins on the side of the neck, passes along the front of the arm, skips the thumb, and is continued over the elongated palm-bones and fingers to the sides of the body again, and to the hind-legs, and to the tail if there is a tail. It is interesting to find that the bones of the bat's skeleton tend to be lightly built as in birds, that the breastbone has likewise a keel for the better



A. PROTECTIVE COLORATION OR CAMOUFLAGING, GIVING ANIMALS A GARMENT OF INVISIBILITY

At the foot of the plate is a Nightjar, with plumage like bark and withering leaves; to the right, resting on a branch, is shown a Chameleon in a green phase amid green surroundings; the insects on the reeds are Locusts; while a green Frog, merged into its surroundings, rests on a leaf near the centre at the top of the picture.

B. ANOTHER EXAMPLE OF PROTECTIVE COLORATION OR CAMOUFLAGE.

A shore scene showing Trout in the pool almost invisible against their background. The Stone Curlews, both adult and young, are very inconspicuous among the stones on the beach.

insertion of the pectoral muscles, and that there is a solidifying of the vertebræ of the back, affording as in birds a firm basis for the wing action. Such similar adaptations to similar needs, occurring in animals not nearly related to one another, are called "convergences," and form a very interesting study. In addition to adaptations which the bat shares with the flying bird, it has many of its own. There are so many nerve-endings on the wing, and often also on special skin-leaves about the ears and nose, that the bat flying in the dusk does not knock against branches or other obstacles. Some say that it is helped by the echoes of its high-pitched voice, but there is no doubt as to its exquisite tactility. That it usually produces only a single young one at a time is a clear adaptation to flight, and similarly the sharp, mountain-top-like cusps on the back teeth are adapted in insectivorous bats for crunching insects.

Whether we think of the triumphant flight of birds, reaching a climax in migration, or of the marvel that a creature of the earth—as a mammal essentially is—should evolve such a mastery of the air as we see in bats, or even of the repeated but splendid failures which parachuting animals illustrate, we gain an impression of the insurgence of living creatures in their characteristic endeavour after fuller well-being.

We have said enough to show how well adapted many animals are to meet the particular difficulties of the haunt which they tenant. But difficulties and limitations are ever arising afresh, and so one fitness follows on another. It is natural, therefore, to pass to the frequent occurrence of protective resemblance, camouflage, and mimicry—the subject of the next article.

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