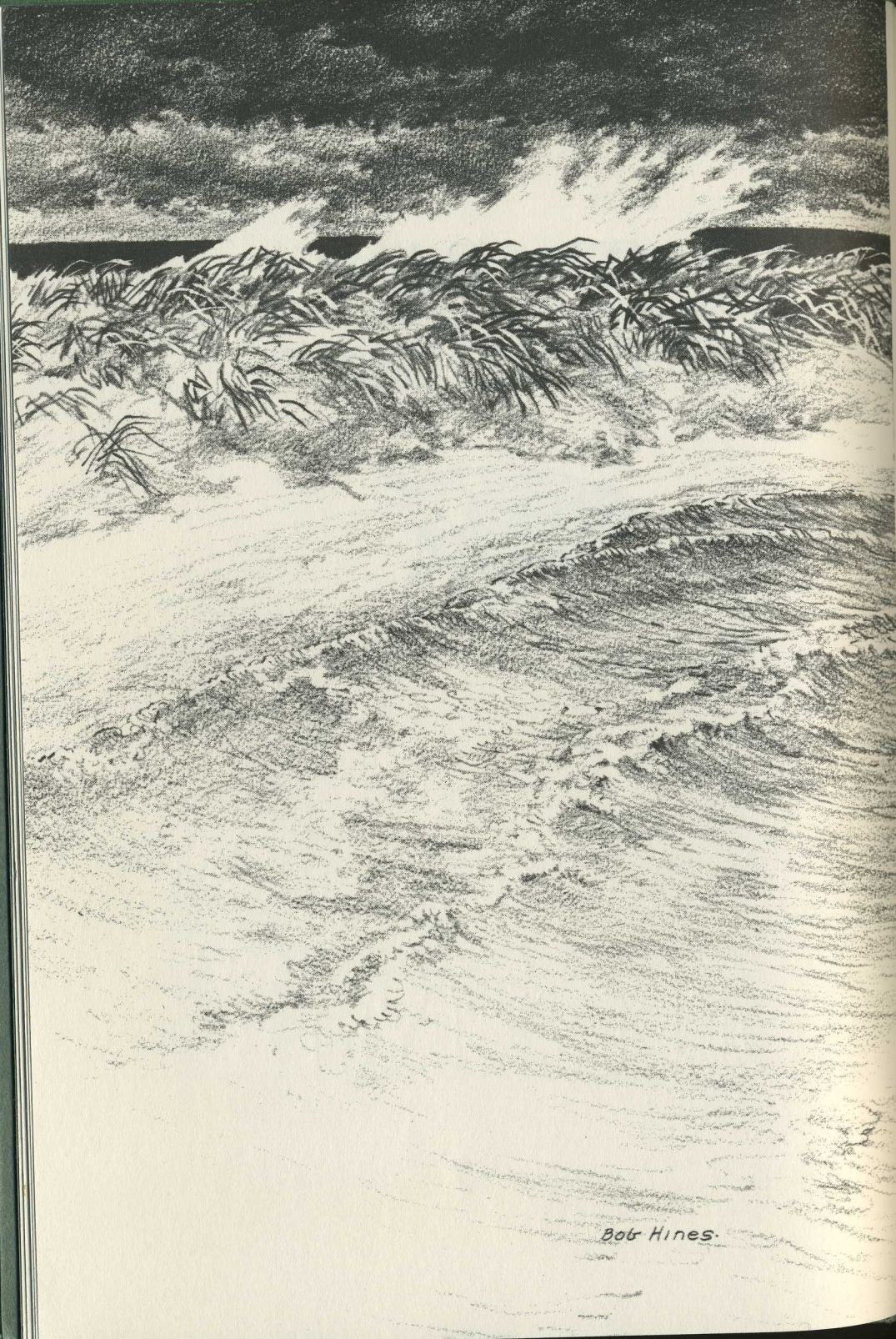




Bob Hines

The Marginal World

THE EDGE of the sea is a strange and beautiful place. All through the long history of Earth it has been an area of unrest where waves have broken heavily against the land, where the tides have pressed forward over the continents, receded, and then returned. For no two successive days is the shore line precisely the same. Not only do the tides advance and retreat in their eternal rhythms, but the level of the sea itself is never at rest. It rises or falls as the glaciers melt or grow, as the floor of the deep ocean basins shifts under its increasing load of sediments, or as the earth's crust along the continental margins warps up or down in adjustment to strain and tension. Today a little more land may belong to the sea, tomorrow a little less. Always the edge of the sea remains an elusive and indefinable boundary.

The shore has a dual nature, changing with the swing of the tides, belonging now to the land, now to the sea. On the ebb tide it knows the harsh extremes of the land world, being exposed to heat and cold, to wind, to rain and drying sun. On the flood tide it is a water world, returning briefly to the relative stability of the open sea.

Only the most hardy and adaptable can survive in a region so mutable, yet the area between the tide lines is crowded with plants and animals. In this difficult world of the shore, life displays its enormous toughness and vitality by occupying almost every conceivable niche. Visibly, it carpets the intertidal rocks; or half hidden, it descends into fissures and crevices, or

hides under boulders, or lurks in the wet gloom of sea caves. Invisibly, where the casual observer would say there is no life, it lies deep in the sand, in burrows and tubes and passageways. It tunnels into solid rock and bores into peat and clay. It encrusts weeds or drifting spars or the hard, chitinous shell of a lobster. It exists minutely, as the film of bacteria that spreads over a rock surface or a wharf piling; as spheres of protozoa, small as pinpricks, sparkling at the surface of the sea; and as Lilliputian beings swimming through dark pools that lie between the grains of sand.

The shore is an ancient world, for as long as there has been an earth and sea there has been this place of the meeting of land and water. Yet it is a world that keeps alive the sense of continuing creation and of the relentless drive of life. Each time that I enter it, I gain some new awareness of its beauty and its deeper meanings, sensing that intricate fabric of life by which one creature is linked with another, and each with its surroundings.

In my thoughts of the shore, one place stands apart for its revelation of exquisite beauty. It is a pool hidden within a cave that one can visit only rarely and briefly when the lowest of the year's low tides fall below it, and perhaps from that very fact it acquires some of its special beauty. Choosing such a tide, I hoped for a glimpse of the pool. The ebb was to fall early in the morning. I knew that if the wind held from the northwest and no interfering swell ran in from a distant storm the level of the sea should drop below the entrance to the pool. There had been sudden ominous showers in the night, with rain like handfuls of gravel flung on the roof. When I looked out into the early morning the sky was full of a gray dawn light but the sun had not yet risen. Water and air were pallid. Across the bay the moon was a luminous disc in the western sky, suspended above the dim line of distant shore—the full August moon, drawing the tide to the low, low levels of the threshold of the alien

sea world. As I watched, a gull flew by, above the spruces. Its breast was rosy with the light of the unrisen sun. The day was, after all, to be fair.

Later, as I stood above the tide near the entrance to the pool, the promise of that rosy light was sustained. From the base of the steep wall of rock on which I stood, a moss-covered ledge jutted seaward into deep water. In the surge at the rim of the ledge the dark fronds of oarweeds swayed, smooth and gleaming as leather. The projecting ledge was the path to the small hidden cave and its pool. Occasionally a swell, stronger than the rest, rolled smoothly over the rim and broke in foam against the cliff. But the intervals between such swells were long enough to admit me to the ledge and long enough for a glimpse of that fairy pool, so seldom and so briefly exposed.

And so I knelt on the wet carpet of sea moss and looked back into the dark cavern that held the pool in a shallow basin. The floor of the cave was only a few inches below the roof, and a mirror had been created in which all that grew on the ceiling was reflected in the still water below.

Under water that was clear as glass the pool was carpeted with green sponge. Gray patches of sea squirts glistened on the ceiling and colonies of soft coral were a pale apricot color. In the moment when I looked into the cave a little elfin starfish hung down, suspended by the merest thread, perhaps by only a single tube foot. It reached down to touch its own reflection, so perfectly delineated that there might have been, not one starfish, but two. The beauty of the reflected images and of the limpid pool itself was the poignant beauty of things that are ephemeral, existing only until the sea should return to fill the little cave.

Whenever I go down into this magical zone of the low water of the spring tides, I look for the most delicately beautiful of all the shore's inhabitants—flowers that are not plant but animal, blooming on the threshold of the deeper sea. In that fairy cave

I was not disappointed. Hanging from its roof were the pendent flowers of the hydroid *Tubularia*, pale pink, fringed and delicate as the wind flower. Here were creatures so exquisitely fashioned that they seemed unreal, their beauty too fragile to exist in a world of crushing force. Yet every detail was functionally useful, every stalk and hydranth and petal-like tentacle fashioned for dealing with the realities of existence. I knew that they were merely waiting, in that moment of the tide's ebbing, for the return of the sea. Then in the rush of water, in the surge of surf and the pressure of the incoming tide, the delicate flower heads would stir with life. They would sway on their slender stalks, and their long tentacles would sweep the returning water, finding in it all that they needed for life.

And so in that enchanted place on the threshold of the sea the realities that possessed my mind were far from those of the land world I had left an hour before. In a different way the same sense of remoteness and of a world apart came to me in a twilight hour on a great beach on the coast of Georgia. I had come down after sunset and walked far out over sands that lay wet and gleaming, to the very edge of the retreating sea. Looking back across that immense flat, crossed by winding, water-filled gullies and here and there holding shallow pools left by the tide, I was filled with awareness that this intertidal area, although abandoned briefly and rhythmically by the sea, is always reclaimed by the rising tide. There at the edge of low water the beach with its reminders of the land seemed far away. The only sounds were those of the wind and the sea and the birds. There was one sound of wind moving over water, and another of water sliding over the sand and tumbling down the faces of its own wave forms. The flats were astir with birds, and the voice of the willet rang insistently. One of them stood at the edge of the water and gave its loud, urgent cry; an answer came from far up the beach and the two birds flew to join each other.

The flats took on a mysterious quality as dusk approached and the last evening light was reflected from the scattered pools and creeks. Then birds became only dark shadows, with no color discernible. Sanderlings scurried across the beach like little ghosts, and here and there the darker forms of the willets stood out. Often I could come very close to them before they would start up in alarm—the sanderlings running, the willets flying up, crying. Black skimmers flew along the ocean's edge silhouetted against the dull, metallic gleam, or they went flitting above the sand like large, dimly seen moths. Sometimes they "skimmed" the winding creeks of tidal water, where little spreading surface ripples marked the presence of small fish.

The shore at night is a different world, in which the very darkness that hides the distractions of daylight brings into sharper focus the elemental realities. Once, exploring the night beach, I surprised a small ghost crab in the searching beam of my torch. He was lying in a pit he had dug just above the surf, as though watching the sea and waiting. The blackness of the night possessed water, air, and beach. It was the darkness of an older world, before Man. There was no sound but the all-enveloping, primeval sounds of wind blowing over water and sand, and of waves crashing on the beach. There was no other visible life—just one small crab near the sea. I have seen hundreds of ghost crabs in other settings, but suddenly I was filled with the odd sensation that for the first time I knew the creature in its own world—that I understood, as never before, the essence of its being. In that moment time was suspended; the world to which I belonged did not exist and I might have been an onlooker from outer space. The little crab alone with the sea became a symbol that stood for life itself—for the delicate, destructible, yet incredibly vital force that somehow holds its place amid the harsh realities of the inorganic world.

The sense of creation comes with memories of a southern coast, where the sea and the mangroves, working together, are

building a wilderness of thousands of small islands off the southwestern coast of Florida, separated from each other by a tortuous pattern of bays, lagoons, and narrow waterways. I remember a winter day when the sky was blue and drenched with sunlight; though there was no wind one was conscious of flowing air like cold clear crystal. I had landed on the surf-washed tip of one of those islands, and then worked my way around to the sheltered bay side. There I found the tide far out, exposing the broad mud flat of a cove bordered by the mangroves with their twisted branches, their glossy leaves, and their long prop roots reaching down, grasping and holding the mud, building the land out a little more, then again a little more.

The mud flats were strewn with the shells of that small, exquisitely colored mollusk, the rose tellin, looking like scattered petals of pink roses. There must have been a colony nearby, living buried just under the surface of the mud. At first the only creature visible was a small heron in gray and rusty plumage—a reddish egret that waded across the flat with the stealthy, hesitant movements of its kind. But other land creatures had been there, for a line of fresh tracks wound in and out among the mangrove roots, marking the path of a raccoon feeding on the oysters that gripped the supporting roots with projections from their shells. Soon I found the tracks of a shore bird, probably a sanderling, and followed them a little; then they turned toward the water and were lost, for the tide had erased them and made them as though they had never been.

Looking out over the cove I felt a strong sense of the interchangeability of land and sea in this marginal world of the shore, and of the links between the life of the two. There was also an awareness of the past and of the continuing flow of time, obliterating much that had gone before, as the sea had that morning washed away the tracks of the bird.

The sequence and meaning of the drift of time were quietly summarized in the existence of hundreds of small snails—the

mangrove periwinkles—browsing on the branches and roots of the trees. Once their ancestors had been sea dwellers, bound to the salt waters by every tie of their life processes. Little by little over the thousands and millions of years the ties had been broken, the snails had adjusted themselves to life out of water, and now today they were living many feet above the tide to which they only occasionally returned. And perhaps, who could say how many ages hence, there would be in their descendants not even this gesture of remembrance for the sea.

The spiral shells of other snails—these quite minute—left winding tracks on the mud as they moved about in search of food. They were horn shells, and when I saw them I had a nostalgic moment when I wished I might see what Audubon saw, a century and more ago. For such little horn shells were the food of the flamingo, once so numerous on this coast, and when I half closed my eyes I could almost imagine a flock of these magnificent flame birds feeding in that cove, filling it with their color. It was a mere yesterday in the life of the earth that they were there; in nature, time and space are relative matters, perhaps most truly perceived subjectively in occasional flashes of insight, sparked by such a magical hour and place.

There is a common thread that links these scenes and memories—the spectacle of life in all its varied manifestations as it has appeared, evolved, and sometimes died out. Underlying the beauty of the spectacle there is meaning and significance. It is the elusiveness of that meaning that haunts us, that sends us again and again into the natural world where the key to the riddle is hidden. It sends us back to the edge of the sea, where the drama of life played its first scene on earth and perhaps even its prelude; where the forces of evolution are at work today, as they have been since the appearance of what we know as life; and where the spectacle of living creatures faced by the cosmic realities of their world is crystal clear.



Patterns of Shore Life

THE EARLY HISTORY of life as it is written in the rocks is exceedingly dim and fragmentary, and so it is not possible to say when living things first colonized the shore, nor even to indicate the exact time when life arose. The rocks that were laid down as sediments during the first half of the earth's history, in the Archeozoic era, have since been altered chemically and physically by the pressure of many thousands of feet of superimposed layers and by the intense heat of the deep regions to which they have been confined during much of their existence. Only in a few places, as in eastern Canada, are they exposed and accessible for study, but if these pages of the rock history ever contained any clear record of life, it has long since been obliterated.

The following pages—the rocks of the next several hundred million years, known as the Proterozoic era—are almost as disappointing. There are immense deposits of iron, which may possibly have been laid down with the help of certain algae and bacteria. Other deposits—strange globular masses of calcium carbonate—seem to have been formed by lime-secreting algae. Supposed fossils or faint impressions in these ancient rocks have been tentatively identified as sponges, jellyfish, or hard-shelled creatures with jointed legs called arthropods, but the more skeptical or conservative scientists regard these traces as having an inorganic origin.

Suddenly, following the early pages with their sketchy rec-

ords, a whole section of the history seems to have been destroyed. Sedimentary rocks representing untold millions of years of pre-Cambrian history have disappeared, having been lost by erosion or possibly, through violent changes in the surface of the earth, brought into a location that now is at the bottom of the deep sea. Because of this loss a seemingly unbridgeable gap in the story of life exists.

The scarcity of fossil records in the early rocks and the loss of whole blocks of sediments may be linked with the chemical nature of the early sea and the atmosphere. Some specialists believe that the pre-Cambrian ocean was deficient in calcium or at least in the conditions that make easily possible the secretion of calcium shells and skeletons. If so, its inhabitants must have been for the most part soft-bodied and so not readily fossilized. A large amount of carbon dioxide in the atmosphere and its relative deficiency in the sea would also have affected the weathering of rock, according to geological theory, so that the sedimentary rocks of pre-Cambrian time must have been repeatedly eroded, washed away, and newly sedimented, with consequent destruction of fossils.

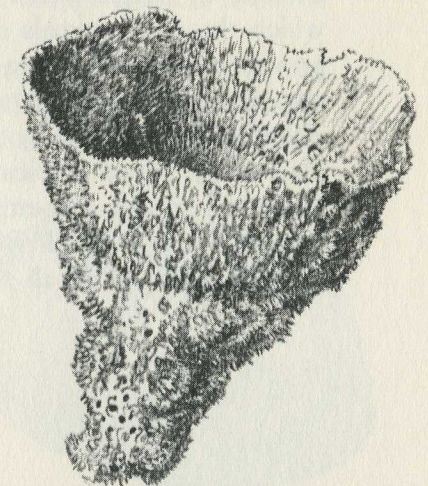
When the record is resumed in the rocks of the Cambrian period, which are about half a billion years old, all the major groups of invertebrate animals (including the principal inhabitants of the shore) suddenly appear, fully formed and flourishing. There are sponges and jellyfish, worms of all sorts, a few simple snail-like mollusks, and arthropods. Algae also are abundant, although no higher plants appear. But the basic plan of each of the large groups of animals and plants that now inhabit the shore had been at least projected in those Cambrian seas, and we may suppose, on good evidence, that the strip between the tide lines 500 million years ago bore at least a general resemblance to the intertidal area of the present stage of earth history.

We may suppose also that for at least the preceding half-

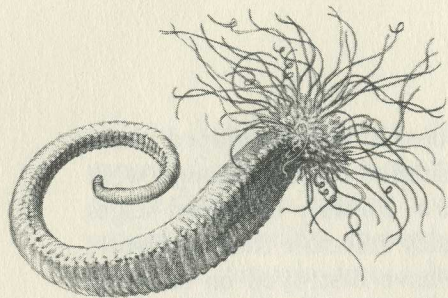
billion years those invertebrate groups, so well developed in the Cambrian, had been evolving from simpler forms, although what they looked like we may never know. Possibly the larval stages of some of the species now living may resemble those ancestors whose remains the earth seems to have destroyed or failed to preserve.

During the hundreds of millions of years since the dawn of the Cambrian, sea life has continued to evolve. Subdivisions of the original basic groups have arisen, new species have been created, and many of the early forms have disappeared as evolution has developed others better fitted to meet the demands of their world. A few of the primitive creatures of Cambrian time have representatives today that are little changed from their early ancestors, but these are the exception. The shore, with its difficult and changing conditions, has been a testing ground in which the precise and perfect adaptation to environment is an indispensable condition of survival.

All the life of the shore—the past and the present—by the very fact of its existence there, gives evidence that it has dealt successfully with the realities of its world—the towering physical realities of the sea itself, and the subtle life relationships that bind each living thing to its own community. The patterns of life as created and shaped by these realities intermingle and overlap so that the major design is exceedingly complex.



Basket sponge



Amphitrite, a worm that inhabits
muddy pockets among rocks.

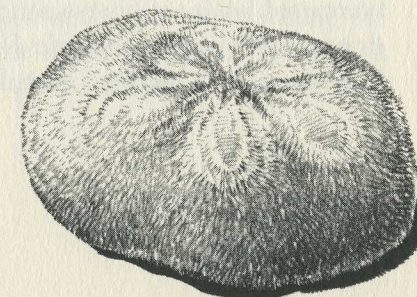
Whether the bottom of the shallow waters and the intertidal area consists of rocky cliffs and boulders, of broad plains of sand, or of coral reefs and shallows determines the visible pattern of life. A rocky coast, even though it is swept by surf, allows life to exist openly through adaptations for clinging to the firm surfaces provided by the rocks and by other structural provisions for dissipating the force of the waves. The visible evidence of living things is everywhere about—a colorful tapestry of seaweeds, barnacles, mussels, and snails covering the rocks—while more delicate forms find refuge in cracks and crevices or by creeping under boulders. Sand, on the other hand, forms a yielding, shifting substratum of unstable nature, its particles incessantly stirred by the waves, so that few living things can establish or hold a place on its surface or even in its upper layers. All have gone below, and in burrows, tubes, and underground chambers the hidden life of the sands is lived. A coast dominated by coral reefs is necessarily a warm coast, its existence made possible by warm ocean currents establishing the climate in which the coral animals can thrive. The reefs, living or dead, provide a hard surface to which living things may cling. Such a coast is somewhat like one bordered by rocky cliffs, but with differences introduced by smothering layers of chalky sediments. The richly varied tropical fauna of coral coasts has therefore developed special adaptations that set it apart from the life of mineral rock or sand. Because the American Atlantic coast includes examples of all three types of shore, the various pat-

terns of life related to the nature of the coast itself are displayed there with beautiful clarity.

Still other patterns are superimposed on the basic geologic ones. The surf dwellers are different from those who live in quiet waters, even if members of the same species. In a region of strong tides, life exists in successive bands or zones, from the high-water mark to the line of the lowest ebb tides; these zones are obscured where there is little tidal action or on sand beaches where life is driven underground. The currents, modifying temperature and distributing the larval stages of sea creatures, create still another world.

Again the physical facts of the American Atlantic coast are such that the observer of its life has spread before him, almost with the clarity of a well-conceived scientific experiment, a demonstration of the modifying effect of tides, surf, and currents. It happens that the northern rocks, where life is lived openly, lie in the region of some of the strongest tides of the world, those within the area of the Bay of Fundy. Here the zones of life created by the tides have the simple graphic force of a diagram. The tidal zones being obscured on sandy shores, one is free there to observe the effect of the surf. Neither strong tides nor heavy surf visits the southern tip of Florida. Here is a typical coral coast, built by the coral animals and the mangroves that multiply and spread in the calm, warm waters—a world whose inhabitants have drifted there on ocean currents from the West Indies, duplicating the strange tropical fauna of that region.

And over all these patterns there are others created by the sea water itself—bringing or withholding food, carrying substances of powerful chemical nature that, for good or ill, affect



Cake urchin,
a sand-dwelling animal

the lives of all they touch. Nowhere on the shore is the relation of a creature to its surroundings a matter of a single cause and effect; each living thing is bound to its world by many threads, weaving the intricate design of the fabric of life.

The problem of breaking waves need not be faced by inhabitants of the open ocean, for they can sink into deep water to avoid rough seas. An animal or plant of the shore has no such means of escape. The surf releases all its tremendous energy as it breaks against the shore, sometimes delivering blows of almost incredible violence. Exposed coasts of Great Britain and other eastern Atlantic islands receive some of the most violent surf in the world, created by winds that sweep across the whole expanse of ocean. It sometimes strikes with a force of two tons to the square foot. The American Atlantic coast, being a sheltered shore, receives no such surf, yet even here the waves of winter storms or of summer hurricanes have enormous size and destructive power. The island of Monhegan on the coast of Maine lies unprotected in the path of such storms and receives their waves on its steep seaward-facing cliffs. In a violent storm the spray from breaking waves is thrown over the crest of White Head, about 100 feet above the sea. In some storms the green water of actual waves sweeps over a lower cliff known as Gull Rock. It is about 60 feet high.

The effect of waves is felt on the bottom a considerable distance offshore. Lobster traps set in water nearly 200 feet deep often are shifted about or have stones carried into them. But the critical problem, of course, is the one that exists on or very close to the shore, where waves are breaking. Very few coasts have completely defeated the attempts of living things to gain a foothold. Beaches are apt to be barren if they are composed of loose coarse sand that shifts in the surf and then dries quickly when the tide falls. Others, of firm sand, though they may look barren, actually sustain a rich fauna in their

deeper layers. A beach composed of many cobblestones that grind against each other in the surf is an impossible home for most creatures. But the shore formed of rocky cliffs and ledges, unless the surf be of extraordinary force, is host to a large and abundant fauna and flora.

Barnacles are perhaps the best example of successful inhabitants of the surf zone. Limpets do almost as well, and so do the small rock periwinkles. The coarse brown seaweeds called wracks or rockweeds possess species that thrive in moderately heavy surf, while others require a degree of protection. After a little experience one can learn to judge the exposure of any shore merely by identifying its fauna and flora. If, for example, there is a broad area covered by the knotted wrack—a long and slender weed that lies like a tangled mass of cordage when the tide is out—if this predominates, we know the shore is a moderately protected one, seldom visited by heavy surf. If, however, there is little or none of the knotted wrack but instead a zone covered by a rockweed of much shorter stature, branching repeatedly, its fronds flattened and tapering at the ends, then we sense more keenly the presence of the open sea and the crushing power of its surf. For the forked wrack and other members of a community of low-growing seaweeds with strong and elastic tissues are sure indicators of an exposed coast and can thrive in seas the knotted wrack cannot endure. And if, on still another shore, there is little vegetation of any sort, but instead only a rock zone whitened by a living snow of barnacles—thousands upon thousands of them raising their sharp-pointed cones to the smother of the surf—we may be sure this coast is quite unprotected from the force of the sea.

The barnacle has two advantages that allow it to succeed where almost all other life fails to survive. Its low conical shape deflects the force of the waves and sends the water rolling off harmlessly. The whole base of the cone, moreover, is fixed to the rock with natural cement of extraordinary strength; to re-

move it one has to use a sharp-bladed knife. And so those twin dangers of the surf zone—the threat of being washed away and of being crushed—have little reality for the barnacle. Yet its existence in such a place takes on a touch of the miraculous when we remember this fact: it was not the adult creature, whose shape and firmly cemented base are precise adaptations to the surf, that gained a foothold here; it was the larva. In the turbulence of heavy seas, the delicate larva had to choose its spot on the wave-washed rocks, to settle there, and somehow not be washed away during those critical hours while its tissues were being reorganized in their transformation to the adult form, while the cement was extruded and hardened, and the shell plates grew up about the soft body. To accomplish all this in heavy surf seems to me a far more difficult thing than is required of the spore of a rockweed; yet the fact remains that the barnacles can colonize exposed rocks where the weeds are unable to gain a footing.

The streamlined form has been adopted and even improved upon by other creatures, some of whom have omitted the permanent attachment to the rocks. The limpet is one of these—a simple and primitive snail that wears above its tissues a shell like the hat of a Chinese coolie. From this smoothly sloping cone the surf rolls away harmlessly; indeed, the blows of falling water only press down more firmly the suction cup of fleshy tissue beneath the shell, strengthening its grip on the rock.

Still other creatures, while retaining a smoothly rounded contour, put out anchor lines to hold their places on the rocks. Such a device is used by the mussels, whose numbers in even a limited area may be almost astronomical. The shells of each animal are bound to the rock by a series of tough threads, each of shining silken appearance. The threads are a kind of natural silk, spun by a gland in the foot. These anchor lines extend out in all directions; if some are broken, the others hold while the damaged lines are being replaced. But most of the threads

are directed forward and in the pounding of storm surf the mussel tends to swing around and head into the seas, taking them on the narrow "prow" and so minimizing their force.

Even the sea urchins can anchor themselves firmly in moderately strong surf. Their slender tube feet, each equipped with a suction disc at its tip, are thrust out in all directions. I have marveled at the green urchins on a Maine shore, clinging to the exposed rock at low water of spring tides, where the beautiful coralline algae spread a rose-colored crust beneath the shining green of their bodies. At that place the bottom slopes away steeply and when the waves at low tide break on the crest of the slope, they drain back to the sea with a strong rush of water. Yet as each wave recedes, the urchins remain on their accustomed stations, undisturbed.

For the long-stalked kelps that sway in dusky forests just below the level of the spring tides, survival in the surf zone is largely a matter of chemistry. Their tissues contain large amounts of alginic acid and its salts, which create a tensile strength and elasticity able to withstand the pulling and pounding of the waves.

Still others—animal and plant—have been able to invade the surf zone by reducing life to a thin creeping mat of cells. In such form many sponges, ascidians, bryozoans, and algae can endure the force of waves. Once removed from the shaping and conditioning effect of surf, however, the same species may take on entirely different forms. The pale green crumb-of-bread sponge lies flat and almost paper-thin on rocks facing toward the sea; back in one of the deep rock pools its tissues build up into thickened masses, sprinkled with the cone-and-crater structure that is one of the marks of the species. Or the golden-star tunicate may expose a simple sheet of jelly to the waves, though in quiet water it hangs down in pendulous lobes flecked with the starry forms of the creatures that comprise it.

As on the sands almost everything has learned to endure the

surf by burrowing down to escape it, so on the rocks some have found safety by boring. Where ancient marl is exposed on the Carolina coast, it is riddled by date mussels. Masses of peat contain the delicately sculptured shells of mollusks called angel wings, seemingly fragile as china, but nevertheless able to bore into clay or rock; concrete piers are drilled by small boring clams; wooden timbers by other clams and isopods. All of these creatures have exchanged their freedom for a sanctuary from the waves, being imprisoned forever within the chambers they have carved.

The vast current systems, which flow through the oceans like rivers, lie for the most part offshore and one might suppose their influence in intertidal matters to be slight. Yet the currents have far-reaching effects, for they transport immense volumes of water over long distances—water that holds its original temperature through thousands of miles of its journey. In this way tropical warmth is carried northward and arctic cold brought far down toward the equator. The currents, probably more than any other single element, are the creators of the marine climate.

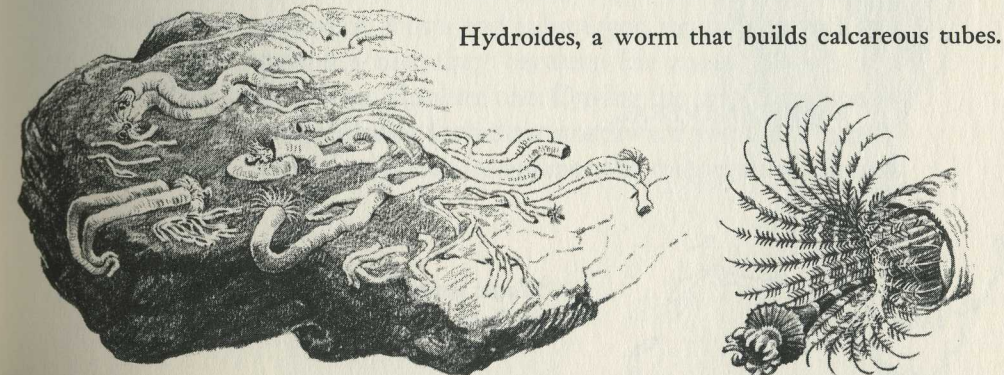
The importance of climate lies in the fact that life, even as broadly defined to include all living things of every sort, exists within a relatively narrow range of temperature, roughly between 32° F. and 210° F. The planet Earth is particularly favorable for life because it has a fairly stable temperature. Especially in the sea, temperature changes are moderate and gradual and many animals are so delicately adjusted to the accustomed water climate that an abrupt or drastic change is fatal. Animals living on the shore and exposed to air temperatures at low tide are necessarily a little more hardy, but even these have their preferred range of heat and cold beyond which they seldom stray.

Most tropical animals are more sensitive to change—especially toward higher temperatures—than northern ones, and this is

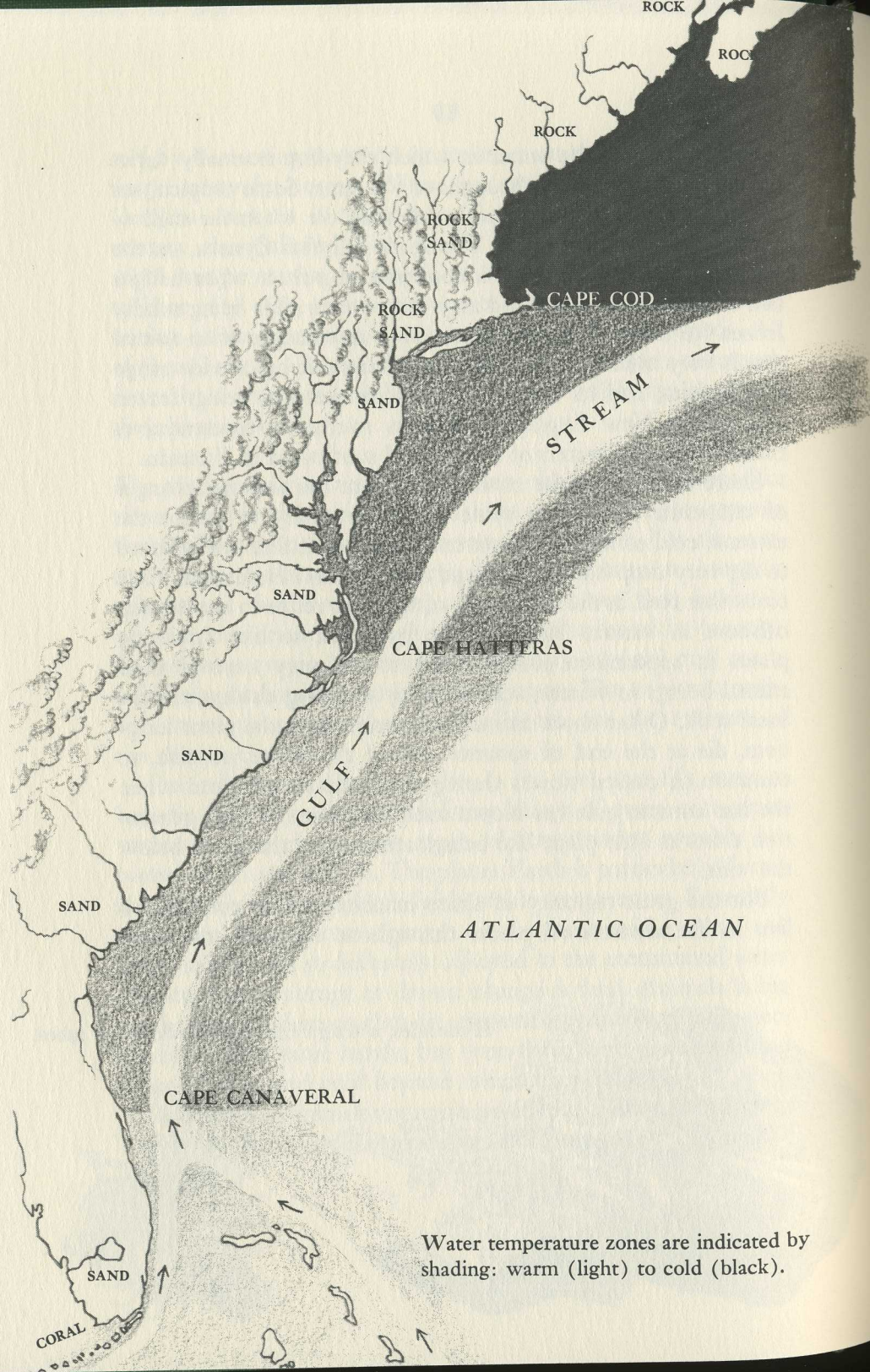
probably because the water in which they live normally varies by only a few degrees throughout the year. Some tropical sea urchins, keyhole limpets, and brittle stars die when the shallow waters heat to about 99° F. The arctic jellyfish *Cyanea*, on the other hand, is so hardy that it continues to pulsate when half its bell is imprisoned in ice, and may revive even after being solidly frozen for hours. The horseshoe crab is an example of an animal that is very tolerant of temperature change. It has a wide range as a species, and its northern forms can survive being frozen into ice in New England, while its southern representatives thrive in tropical waters of Florida and southward to Yucatán.

Shore animals for the most part endure the seasonal changes of temperate coasts, but some find it necessary to escape the extreme cold of winter. Ghost crabs and beach fleas are believed to dig very deep holes in the sand and go into hibernation. Mole crabs that feed in the surf much of the year retire to the bottom offshore in winter. Many of the hydroids, so like flowering plants in appearance, shrink down to the very core of their animal beings in winter, withdrawing all living tissues into the basal stalk. Other shore animals, like annuals in the plant kingdom, die at the end of summer. All of the white jellyfish, so common in coastal waters during the summer, are dead when the last autumn gale has blown itself out, but the next generation exists as little plant-like beings attached to the rocks below the tide.

For the great majority of shore inhabitants that continue to live in the accustomed places throughout the year, the most



Hydroides, a worm that builds calcareous tubes.



dangerous aspect of winter is not cold but ice. In years when much shore ice is formed, the rocks may be scraped clean of barnacles, mussels, and seaweeds simply by the mechanical action of ice grinding in the surf. After this happens, several growing seasons separated by moderate winters may be needed to restore the full community of living creatures.

Because most sea animals have definite preferences as to aquatic climate, it is possible to divide the coastal waters of eastern North America into zones of life. While variation in the temperature of the water within these zones is in part a matter of the advance from southern to northern latitudes, it is also strongly influenced by the pattern of the ocean currents—the sweep of warm tropical water carried northward in the Gulf Stream, and the chill Labrador Current creeping down from the north on the landward border of the Stream, with complex intermixing of warm and cold water between the boundaries of the currents.

From the point where it pours through the Florida straits up as far as Cape Hatteras, the Stream follows the outer edge of the continental shelf, which varies greatly in width. At Jupiter Inlet on the east coast of Florida this shelf is so narrow that one can stand on shore and look out across emerald-green shallows to the place where the water suddenly takes on the intense blue of the Stream. At about this point there seems to exist a temperature barrier, separating the tropical fauna of southern Florida and the Keys from the warm-temperate fauna of the area lying between Cape Canaveral and Cape Hatteras. Again at Hatteras the shelf becomes narrow, the Stream swings closer inshore, and the northward-moving water filters through a confused pattern of shoals and submerged sandy hills and valleys. Here again is a boundary between life zones, though it is a shifting and far from absolute one. During the winter, temperatures at Hatteras probably forbid the northward passage of migratory warm-water forms, but in summer the temperature barriers

break down, the invisible gates open, and these same species may range far toward Cape Cod.

From Hatteras north the shelf broadens, the Stream moves far offshore, and there is a strong infiltration and mixing of colder water from the north, so that the progressive chilling is speeded. The difference in temperature between Hatteras and Cape Cod is as great as one would find on the opposite side of the Atlantic between the Canary Islands and southern Norway—a distance five times as long. For migratory sea fauna this is an intermediate zone, which cold-water forms enter in winter, and warm-water species in summer. Even the resident fauna has a mixed, indeterminate character, for this area seems to receive some of the more temperature-tolerant forms from both north and south, but to have few species that belong to it exclusively.

Cape Cod has long been recognized in zoology as marking the boundary of the range for thousands of creatures. Thrust far into the sea, it interferes with the passage of the warmer waters from the south and holds the cold waters of the north within the long curve of its shore. It is also a point of transition to a different kind of coast. The long sand strands of the south are replaced by rocks, which come more and more to dominate the coastal scene. They form the sea bottom as well as its shores; the same rugged contours that appear in the land forms of this region lie drowned and hidden from view offshore. Here zones of deep water, with accompanying low temperatures, lie generally closer to the shore than they do farther south, with interesting local effects on the populations of shore animals. Despite the deep in-shore waters, the numerous islands and the jaggedly indented coast create a large intertidal area and so provide for a rich shore fauna. This is the cold-temperate region, inhabited by many species unable to tolerate the warm water south of the Cape. Partly because of the low temperatures and partly because of the rocky nature of the shore, heavy growths of seaweeds cover the ebb-tide rocks with a blanket of various hues, herds of peri-

winkles graze, and the shore is here whitened by millions of barnacles or there darkened by millions of mussels.

Beyond, in the waters bathing Labrador, southern Greenland, and parts of Newfoundland, the temperature of the sea and the nature of its flora and fauna are subarctic. Still farther to the north is the arctic province, with limits not yet precisely defined.

Although these basic zones are still convenient and well-founded divisions of the American coast, it became clear by about the third decade of the twentieth century that Cape Cod was not the absolute barrier it had once been for warm-water species attempting to round it from the south. Curious changes have been taking place, with many animals invading this cold-temperate zone from the south and pushing up through Maine and even into Canada. This new distribution is, of course, related to the widespread change of climate that seems to have set in about the beginning of the century and is now well recognized—a general warming-up noticed first in arctic regions, then in subarctic, and now in the temperate areas of northern states. With warmer ocean waters north of Cape Cod, not only the adults but the critically important young stages of various southern animals have been able to survive.

One of the most impressive examples of northward movement is provided by the green crab, once unknown north of the Cape, now familiar to every clam fisherman in Maine because of its habit of preying on the young stages of the clam. Around the turn of the century, zoological manuals gave its range as New Jersey to Cape Cod. In 1905 it was reported near Portland, and by 1930 specimens had been collected in Hancock County, about midway along the Maine coast. During the following decade it moved along to Winter Harbor, and in 1951 was found at Lubec. Then it spread up along the shores of Passamaquoddy Bay and crossed to Nova Scotia.

With higher water temperatures the sea herring is becoming

scarce in Maine. The warmer waters may not be the only cause, but they are undoubtedly responsible in part. As the sea herring decline, other kinds of fish are coming in from the south. The menhaden is a larger member of the herring family, used in enormous quantities for manufacturing fertilizer, oils, and other industrial products. In the 1880's there was a fishery for menhaden in Maine, then they disappeared and for many years were confined almost entirely to areas south of New Jersey. About 1950, however, they began to return to Maine waters, followed by Virginia boats and fishermen. Another fish of the same tribe, called the round herring, is also ranging farther north. In the 1920's Professor Henry Bigelow of Harvard University reported it as occurring from the Gulf of Mexico to Cape Cod, and pointed out that it was rare anywhere on the Cape. (Two caught at Provincetown were preserved in the Museum of Comparative Zoölogy at Harvard.) In the 1950's, however, immense schools of this fish appeared in Maine waters, and the fishing industry began experiments with canning it.

Many other scattered reports follow the same trend. The mantis shrimp, formerly barred by the Cape, has now rounded it and spread into the southern part of the Gulf of Maine. Here and there the soft-shell clam shows signs of being adversely affected by warm summer temperatures and the hard-shell species is replacing it in New York waters. Whiting, once only summer fish north of the Cape, now are caught there throughout the year, and other fish once thought distinctively southern are able to spawn along the coast of New York, where their delicate juvenile stages formerly were killed by the cold winters.

Despite the present exceptions, the Cape Cod—Newfoundland coast is typically a zone of cool waters inhabited by a boreal flora and fauna. It displays strong and fascinating affinities with distant places of the northern world, linked by the unifying force of the sea with arctic waters and with the coasts

of the British Isles and Scandinavia. So many of its species are duplicated in the eastern Atlantic that a handbook for the British Isles serves reasonably well for New England, covering probably 80 per cent of the seaweeds and 60 per cent of the marine animals. On the other hand, the American boreal zone has stronger ties with the arctic than does the British coast. One of the large Laminarian seaweeds, the arctic kelp, comes down to the Maine coast but is absent in the eastern Atlantic. An arctic sea anemone occurs in the western North Atlantic abundantly down to Nova Scotia and less numerous in Maine, but on the other side misses Great Britain and is confined to colder waters farther north. The occurrence of many species such as the green sea urchin, the blood-red starfish, the cod, and the herring are examples of a distribution that is circum-boreal, extending right around the top of the earth and brought about through the agency of cold currents from melting glaciers and drifting pack ice that carry representatives of the northern faunas down into the North Pacific and North Atlantic.

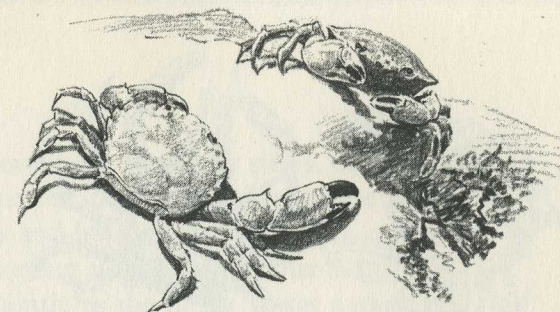
The existence of so strong a common element between the faunas and floras of the two coasts of the North Atlantic suggests that the means of crossing must be relatively easy. The Gulf Stream carries many migrants away from American shores. The distance to the opposite side is great, however, and the situation is complicated by the short larval life of most species and the fact that shallow waters must be within reach when the time comes for assuming the life of the adult. In this northern part of the Atlantic intermediate way-stations are provided by submerged ridges, shallows, and islands, and the crossing may be broken into easy stages. In some earlier geologic times these shallows were even more extensive, so over long periods both active and involuntary migration across the Atlantic have been feasible.

In lower latitudes the deep basin of the Atlantic must be crossed, where few islands or shallows exist. Even here some

transfer of larvae and adults takes place. The Bermuda Islands, after being raised above the sea by volcanic action, received their whole fauna as immigrants from the West Indies via the Gulf Stream. And on a smaller scale the long transatlantic crossings have been accomplished. Considering the difficulties, an impressive number of West Indian species are identical with, or closely related to African species, apparently having crossed in the Equatorial Current. They include species of starfish, shrimp, crayfish, and mollusks. Where such a long crossing has been made it is logical to assume that the migrants were adults, traveling on floating timber or drifting seaweed. In modern times, several African mollusks and starfish have been reported as arriving at the Island of St. Helena by these means.

The records of paleontology provide evidence of the changing shapes of continents and the changing flow of the ocean currents, for these earlier earth patterns account for the otherwise mysterious present distribution of many plants and animals. Once, for example, the West Indian region of the Atlantic was in direct communication, via sea currents, with the distant waters of the Pacific and Indian Oceans. Then a land bridge built up between the Americas, the Equatorial Current turned back on itself to the east, and a barrier to the dispersal of sea creatures was erected. But in species living today we find indications of how it was in the past. Once I discovered a curious little mollusk living in a meadow of turtle grass on the floor of a quiet bay among Florida's Ten Thousand Islands. It was the same bright green as the grass, and its little body was much too large for its thin shell, out of which it bulged. It was one of the scaphanders, and its nearest living relatives are inhabitants of the Indian Ocean. And on the beaches of the Carolinas I have found rocklike masses of calcareous tubes, secreted by colonies of a dark-bodied little worm. It is almost unknown in the Atlantic; again its relatives are Pacific and Indian Ocean forms.

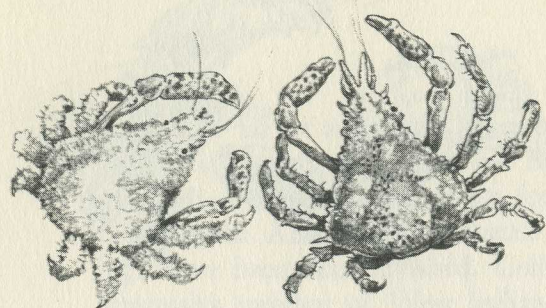
Mud crabs



And so transport and wide dispersal are a continuing, universal process—an expression of the need of life to reach out and occupy all habitable parts of the earth. In any age the pattern is set by the shape of the continents and the flow of the currents; but it is never final, never completed.

On a shore where tidal action is strong and the range of the tide is great, one is aware of the ebb and flow of water with a daily, hourly awareness. Each recurrent high tide is a dramatic enactment of the advance of the sea against the continents, pressing up to the very threshold of the land, while the ebbs expose to view a strange and unfamiliar world. Perhaps it is a broad mud flat where curious holes, mounds, or tracks give evidence of a hidden life alien to the land; or perhaps it is a meadow of rockweeds lying prostrate and sodden now that the sea has left them, spreading a protective cloak over all the animal life beneath them. Even more directly the tides address the sense of hearing, speaking a language of their own distinct from the voice of the surf. The sound of a rising tide is heard most clearly on shores removed from the swell of the open ocean. In the stillness of night the strong waveless surge of a rising tide creates a confused tumult of water sounds—swashings and swirlings and a continuous slapping against the rocky rim of the land. Sometimes there are undertones of murmurings and whisperings; then suddenly all lesser sounds are obliterated by a torrential inpouring of water.

On such a shore the tides shape the nature and behavior of life. Their rise and fall give every creature that lives be-



Decorator crabs

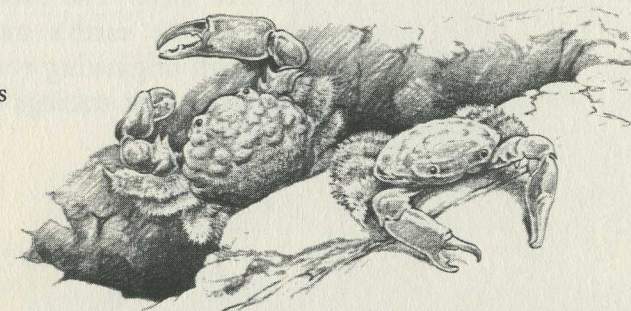
tween the high- and low-water lines a twice-daily experience of land life. For those that live near the low-tide line the exposure to sun and air is brief; for those higher on the shore the interval in an alien environment is more prolonged and demands greater powers of endurance. But in all the intertidal area the pulse of life is adjusted to the rhythm of the tides. In a world that belongs alternately to sea and land, marine animals, breathing oxygen dissolved in sea water, must find ways of keeping moist; the few air breathers who have crossed the high-tide line from the land must protect themselves from drowning in the flood tide by bringing with them their own supply of oxygen. When the tide is low there is little or no food for most intertidal animals, and indeed the essential processes of life usually have to be carried on while water covers the shore. The tidal rhythm is therefore reflected in a biological rhythm of alternating activity and quiescence.

On a rising tide, animals that live deep in sand come to the surface, or thrust up the long breathing tubes or siphons, or begin to pump water through their burrows. Animals fixed to rocks open their shells or reach out tentacles to feed. Predators and grazers move about actively. When the water ebbs away the sand dwellers withdraw into the deep wet layers; the rock fauna brings into use all its varied means for avoiding desiccation. Worms that build calcareous tubes draw back into them, sealing the entrance with a modified gill filament that fits like a cork in a bottle. Barnacles close their shells, holding the moisture

around their gills. Snails draw back into their shells, closing the doorlike operculum to shut out the air and keep some of the sea's wetness within. Scuds and beach fleas hide under rocks or weeds, waiting for the incoming tide to release them.

All through the lunar month, as the moon waxes and wanes, so the moon-drawn tides increase or decline in strength and the lines of high and low water shift from day to day. After the full moon, and again after the new moon, the forces acting on the sea to produce the tide are stronger than at any other time during the month. This is because the sun and moon then are directly in line with the earth and their attractive forces are added together. For complex astronomical reasons, the greatest tidal effect is exerted over a period of several days immediately after the full and the new moon, rather than at a time precisely coinciding with these lunar phases. During these periods the flood tides rise higher and the ebb tides fall lower than at any other time. These are called the "spring tides" from the Saxon "sprungen." The word refers not to a season, but to the brimming fullness of the water causing it to "spring" in the sense of a strong, active movement. No one who has watched a new-moon tide pressing against a rocky cliff will doubt the appropriateness of the term. In its quarter phases, the moon exerts its attraction at right angles to the pull of the sun so the two forces interfere with each other and the tidal movements are slack. Then the water neither rises as high nor falls as low as on the spring tides. These sluggish tides are called the "neaps"—a word that goes back to old Scandinavian roots meaning "barely touching" or "hardly enough."

On the Atlantic coast of North America the tides move in



Knobbed crabs

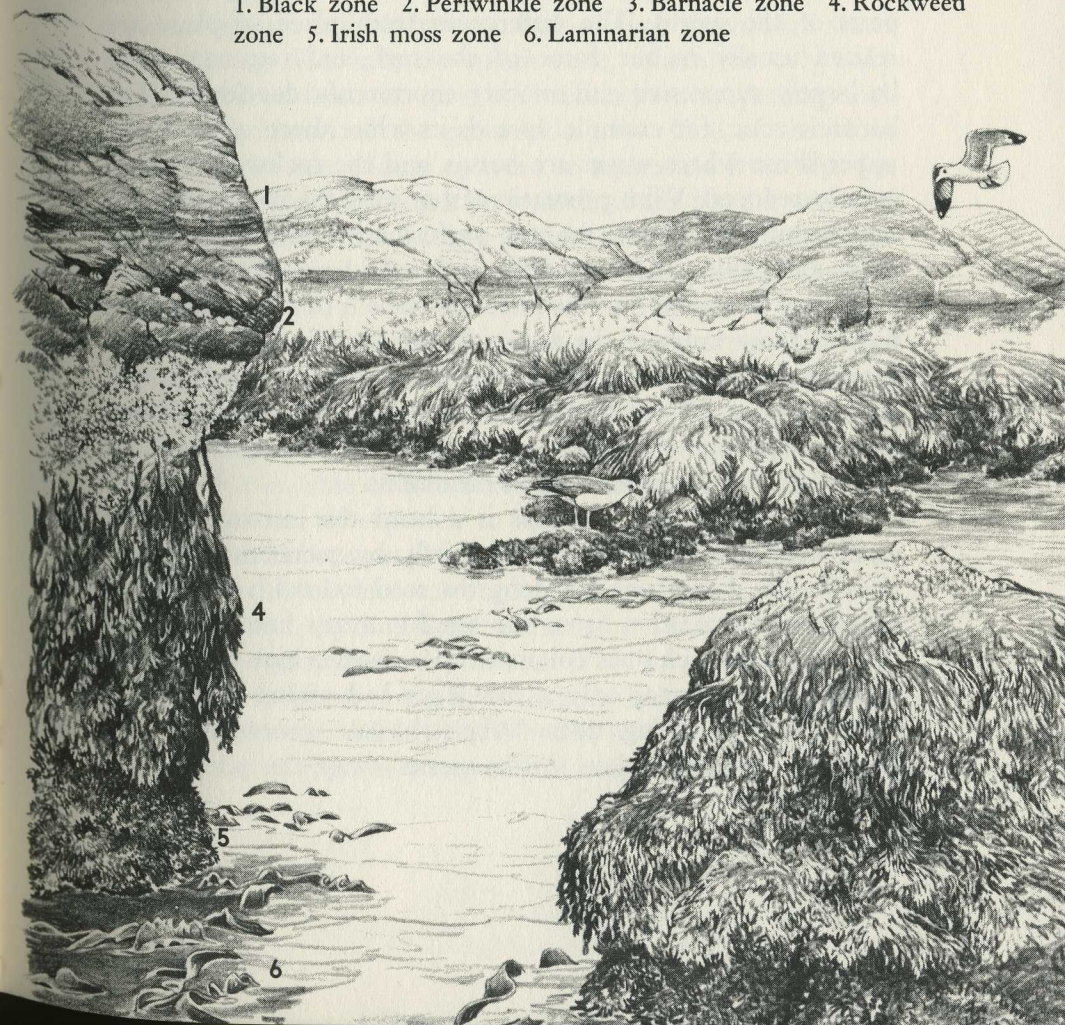
the so-called semidiurnal rhythm, with two high and two low waters in each tidal day of about 24 hours and 50 minutes. Each low tide follows the previous low by about 12 hours and 25 minutes, although slight local variations are possible. A like interval, of course, separates the high tides.

The range of tide shows enormous differences over the earth as a whole and even on the Atlantic coast of the United States there are important variations. There is a rise and fall of only a foot or two around the Florida Keys. On the long Atlantic coast of Florida the spring tides have a range of 3 to 4 feet, but a little to the north, among the Sea Islands of Georgia, these tides have an 8-foot rise. Then in the Carolinas and northward to New England they move less strongly, with spring tides of 6 feet at Charleston, South Carolina, 3 feet at Beaufort, North Carolina, and 5 feet at Cape May, New Jersey. Nantucket Island has little tide, but on the shores of Cape Cod Bay, less than 30 miles away, the spring tide range is 10 to 11 feet. Most of the rocky coast of New England falls within the zone of the great tides of the Bay of Fundy. From Cape Cod to Passamaquoddy Bay the amplitude of their range varies but is always considerable: 10 feet at Provincetown, 12 at Bar Harbor, 20 at Eastport, 22 at Calais. The conjunction of strong tides and a rocky shore, where much of the life is exposed, creates in this area a beautiful demonstration of the power of the tides over living things.

As day after day these great tides ebb and flow over the rocky rim of New England, their progress across the shore is visibly marked in stripes of color running parallel to the sea's edge. These bands, or zones, are composed of living things and reflect the stages of the tide, for the length of time that a particular level of shore is uncovered determines, in large measure, what can live there. The hardest species live in the upper zones. Some of the earth's most ancient plants—the blue-green algae—though originating eons ago in the sea, have emerged from it to form dark tracings on the rocks above the

high-tide line, a black zone visible on rocky shores in all parts of the world. Below the black zone, snails that are evolving toward a land existence browse on the film of vegetation or hide in seams and crevices in the rocks. But the most conspicuous zone begins at the upper line of the tides. On an open shore with moderately heavy surf, the rocks are whitened by the crowded millions of the barnacles just below the high-tide line. Here and there the white is interrupted by mussels growing in patches of darkest blue. Below them the seaweeds come in—

1. Black zone 2. Periwinkle zone 3. Barnacle zone 4. Rockweed zone 5. Irish moss zone 6. Laminarian zone



the brown fields of the rockweeds. Toward the low-tide line the Irish moss spreads its low cushioning growth—a wide band of rich color that is not fully exposed by the sluggish movements of some of the neap tides, but appears on all of the greater tides. Sometimes the reddish brown of the moss is splashed with the bright green tangles of another seaweed, a hairlike growth of wiry texture. The lowest of the spring tides reveal still another zone during the last hour of their fall—that sub-tide world where all the rock is painted a deep rose hue by the lime-secreting seaweeds that encrust it, and where the gleaming brown ribbons of the large kelps lie exposed on the rocks.

With only minor variations, this pattern of life exists in all parts of the world. The differences from place to place are related usually to the force of the surf, and one zone may be largely suppressed and another enormously developed. The barnacle zone, for example, spreads its white sheets over all the upper shore where waves are heavy, and the rockweed zone is greatly reduced. With protection from surf, the rockweeds not only occupy the middle shore in profusion but invade the upper rocks and make conditions difficult for the barnacles.

Perhaps in a sense the true intertidal zone is that band between high and low water of the neap tides, an area that is completely covered and uncovered during each tidal cycle, or twice during every day. Its inhabitants are the typical shore animals and plants, requiring some daily contact with the sea but able to endure limited exposure to land conditions.

Above high water of neaps is a band that seems more of earth than of sea. It is inhabited chiefly by pioneering species; already they have gone far along the road toward land life and can endure separation from the sea for many hours or days. One of the barnacles has colonized these higher high-tide rocks, where the sea comes only a few days and nights out of the month, on the spring tides. When the sea returns it brings food and oxygen, and in season carries away the young into

the nursery of the surface waters; during these brief periods the barnacle is able to carry on all the processes necessary for life. But it is left again in an alien land world when the last of these highest tides of the fortnight ebbs away; then its only defense is the firm closing of the plates of its shell to hold some of the moisture of the sea about its body. In its life brief and intense activity alternates with long periods of a quiescent state resembling hibernation. Like the plants of the Arctic, which must crowd the making and storing of food, the putting forth of flowers, and the forming of seeds into a few brief weeks of summer, this barnacle has drastically adjusted its way of life so that it may survive in a region of harsh conditions.

Some few sea animals have pushed on even above high water of the spring tides into the splash zone, where the only salty moisture comes from the spray of breaking waves. Among such pioneers are snails of the periwinkle tribe. One of the West Indian species can endure months of separation from the sea. Another, the European rock periwinkle, waits for the waves of the spring tides to cast its eggs into the sea, in almost all activities except the vital one of reproduction being independent of the water.

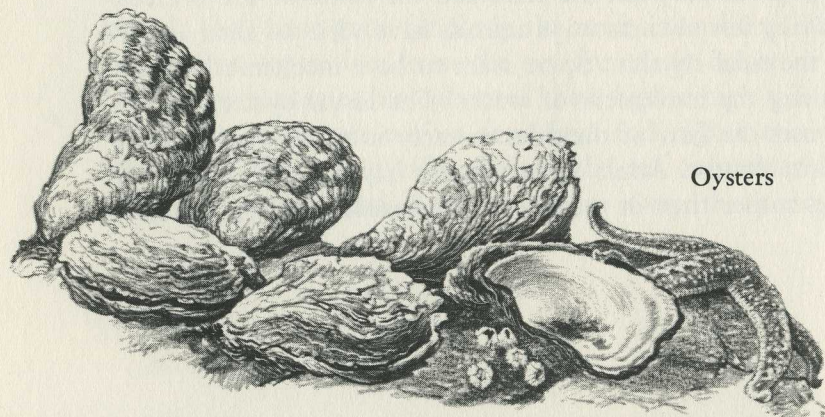
Below the low water of neaps are the areas exposed only as the rhythmic swing of the tides falls lower and lower, approaching the level of the springs. Of all the intertidal zone this region is linked most closely with the sea. Many of its inhabitants are offshore forms, able to live here only because of the briefness and infrequency of exposure to the air.

The relation between the tides and the zones of life is clear, but in many less obvious ways animals have adjusted their activities to the tidal rhythm. Some seem to be a mechanical matter of utilizing the movement of water. The larval oyster, for example, uses the flow of the tides to carry it into areas favorable for its attachment. Adult oysters live in bays or sounds or river estuaries rather than in water of full oceanic salinity, and so it

is to the advantage of the race for the dispersal of the young stages to take place in a direction away from the open sea. When first hatched the larvae drift passively, the tidal currents carrying them now toward the sea, now toward the headwaters of estuaries or bays. In many estuaries the ebb tide runs longer than the flood, having the added push and volume of stream discharge behind it, and the resulting seaward drift over the whole two-week period of larval life would carry the young oysters many miles to sea. A sharp change of behavior sets in, however, as the larvae grow older. They now drop to the bottom while the tide ebbs, avoiding the seaward drift of water, but with the return of the flood they rise into the currents that are pressing upstream, and so are carried into regions of lower salinity that are favorable for their adult life.

Others adjust the rhythm of spawning to protect their young from the danger of being carried into unsuitable waters. One of the tube-building worms living in or near the tidal zone follows a pattern that avoids the strong movements of the spring tides. It releases its larvae into the sea every fortnight on the neap tides, when the water movements are relatively sluggish; the young worms, which have a very brief swimming stage, then have a good chance of remaining within the most favorable zone of the shore.

There are other tidal effects, mysterious and intangible. Sometimes spawning is synchronized with the tides in a way that suggests response to change of pressure or to the difference



Oysters

between still and flowing water. A primitive mollusk called the chiton spawns in Bermuda when the low tide occurs early in the morning, with the return flow of water setting in just after sunrise. As soon as the chitons are covered with water they shed their spawn. One of the Japanese nereid worms spawns only on the strongest tides of the year, near the new- and full-moon tides of October and November, presumably stirred in some obscure way by the amplitude of the water movements.

Many other animals, belonging to quite unrelated groups throughout the whole range of sea life, spawn according to a definitely fixed rhythm that may coincide with the full moon or the new moon or its quarters, but whether the effect is produced by the altered pressure of the tides or the changing light of the moon is by no means clear. For example, there is a sea urchin in Tortugas that spawns on the night of the full moon, and apparently only then. Whatever the stimulus may be, all the individuals of the species respond to it, assuring the simultaneous release of immense numbers of reproductive cells. On the coast of England one of the hydroids, an animal of plant-like appearance that produces tiny medusae or jellyfish, releases these medusae during the moon's third quarter. At Woods Hole on the Massachusetts coast a clamlike mollusk spawns heavily between the full and the new moon but avoids the first quarter. And a nereid worm at Naples gathers in its nuptial swarms during the quarters of the moon but never when the moon is new or full; a related worm at Woods Hole shows no such correlation although exposed to the same moon and to stronger tides.

In none of these examples can we be sure whether the animal is responding to the tides or, as the tides themselves do, to the influence of the moon. With plants, however, the situation is different, and here and there we find scientific confirmation of the ancient and world-wide belief in the effect of moonlight on vegetation. Various bits of evidence suggest that the rapid

multiplication of diatoms and other members of the plant plankton is related to the phases of the moon. Certain algae in river plankton reach the peak of their abundance at the full moon. One of the brown seaweeds on the coast of North Carolina releases its reproductive cells only on the full moon, and similar behavior has been reported for other seaweeds in Japan and other parts of the world. These responses are generally explained as the effect of varying intensities of polarized light on protoplasm.

Other observations suggest some connection between plants and the reproduction and growth of animals. Rapidly maturing herring collect around the edge of concentrations of plant plankton, although the fully adult herring may avoid them. Spawning adults, eggs, and young of various other marine creatures are reported to occur more often in dense phytoplankton than in sparse patches. In significant experiments, a Japanese scientist discovered he could induce oysters to spawn with an extract obtained from sea lettuce. The same seaweed produces a substance that influences growth and multiplication of diatoms, and is itself stimulated by water taken from the vicinity of a heavy growth of rockweeds.

The whole subject of the presence in sea water of the so-called "ectocrines" (external secretions or products of metabolism) has so recently become one of the frontiers of science that actual information is fragmentary and tantalizing. It appears, however, that we may be on the verge of solving some of the riddles that have plagued men's minds for centuries. Though the subject lies in the misty borderlands of advancing knowledge, almost everything that in the past has been taken for granted, as well as problems considered insoluble, bear renewed thought in the light of the discovery of these substances.

In the sea there are mysterious comings and goings, both in space and time: the movements of migratory species, the strange phenomenon of succession by which, in one and the same area,

one species appears in profusion, flourishes for a time, and then dies out, only to have its place taken by another and then another, like actors in a pageant passing before our eyes. And there are other mysteries. The phenomenon of "red tides" has been known from early days, recurring again and again down to the present time—a phenomenon in which the sea becomes discolored because of the extraordinary multiplication of some minute form, often a dinoflagellate, and in which there are disastrous side effects in the shape of mass mortalities among fish and some of the invertebrates. Then there is the problem of curious and seemingly erratic movements of fish, into or away from certain areas, often with sharp economic consequences. When the so-called "Atlantic water" floods the south coast of England, herring become abundant within the range of the Plymouth fisheries, certain characteristic plankton animals occur in profusion, and certain species of invertebrates flourish in the intertidal zone. When, however, this water mass is replaced by Channel water, the cast of characters undergoes many changes.

In the discovery of the biological role played by the sea water and all it contains, we may be about to reach an understanding of these old mysteries. For it is now clear that in the sea nothing lives to itself. The very water is altered, in its chemical nature and in its capacity for influencing life processes, by the fact that certain forms have lived within it and have passed on to it new substances capable of inducing far-reaching effects. So the present is linked with past and future, and each living thing with all that surrounds it.