one can look down into the blue so far that one would hesitate to set foot in so bottomless a pool. Clouds drift across it and wind ripples scud over its surface, but little else moves there, and the pool belongs to the rock and the plants and the sky.

In another high pool nearby, the green tube-weed rises from all of the floor. By some magic the pool transcends its realities of rock and water and plants, and out of these elements creates the illusion of another world. Looking into the pool, one sees no water but instead a pleasant landscape of hills and valleys with scattered forests. Yet the illusion is not so much that of an actual landscape as of a painting of one; like the strokes of a skillful artist's brush, the individual fronds of the algae do not literally portray trees, they merely suggest them. But the artistry of the pool, as of the painter, creates the image and the impression.

Little or no animal life is visible in any of these high pools —perhaps a few periwinkles and a scattering of little amber isopods. Conditions are difficult in all pools high on the shore because of the prolonged absence of the sea. The temperature of the water may rise many degrees, reflecting the heat of the day. The water freshens under heavy rains or becomes more salty under a hot sun. It varies between acid and alkaline in a short time through the chemical activity of the plants. Lower on the shore the pools provide far more stable conditions, and both plants and animals are able to live at higher levels than they could on open rock. The tide pools, then, have the effect of moving the life zones a little higher on the shore. Yet they, too, are affected by the duration of the sea's absence, and the inhabitants of a high pool are very different from those of a low-level pool that is separated from the sea only at long intervals and then briefly.

The highest of the pools scarcely belong to the sea at all; they hold the rains and receive only an occasional influx of sea water from storm surf or very high tides. But the gulls

fly up from their hunting at the sea's edge, bringing a sea urchin or a crab or a mussel to drop on the rocks, in this way shattering the hard shelly covering and exposing the soft parts within. Bits of urchin tests or crab claws or mussel shells find their way into the pools, and as they disintegrate their limy substance enters into the chemistry of the water, which then becomes alkaline. A little one-celled plant called Sphaerella finds this a favorable climate for growth—a minute, globular bit of life almost invisible as an individual, but in its millions turning the waters of these high pools red as blood. Apparently the alkalinity is a necessary condition; other pools, outwardly similar except for the chance circumstance that they contain no shells, have none of the tiny crimson balls.

Even the smallest pools, filling depressions no larger than a teacup, have some life. Often it is a thin patch of scores of the little seashore insect, *Anurida maritima*—"the wingless one who goes to sea." These small insects run on the surface film when the water is undisturbed, crossing easily from one shore of a pool to another. Even the slightest rippling causes them to drift helplessly, however, so that scores or hundreds of them come together by chance, becoming conspicuous only as they form thin, leaflike patches on the water. A single Anurida is small as a gnat. Under a lens, it seems to be clothed in blue-gray velvet through which many bristles or hairs protrude. The bristles hold a film of air about the body of the insect when it enters the water, and so it need not return to the upper shore when the tide rises. Wrapped in its glistening air blanket, dry and provided with air for breathing, it waits in cracks and crevices until the tide ebbs again. Then it emerges to roam over the rocks, searching for the bodies of fish and crabs and the dead mollusks and barnacles that provide its food, for it is one of the scavengers that play a part in the economy of the sea, keeping the organic materials in circulation.

And often I find the pools of the upper third of the shore

Potamilla,
a tube-building worm

lined with a brown velvety coating. My fingers, exploring, are able to peel it off the rocks in thin smooth-surfaced sheets like parchment. It is one of the brown seaweeds called Ralfsia; it appears on the rocks in small, lichen-like growths or, as here, spreading its thin crust over extensive areas. Wherever it grows its presence changes the nature of a pool, for it provides the shelter that many small creatures seek so urgently. Those small enough to creep in under it—to inhabit the dark pockets of space between the encrusting weed and the rock—have found security against being washed away by the surf. Looking at these pools with their velvet lining, one would say there is little life here—only a sprinkling of periwinkles browsing, their shells rocking gently as they scrape at the surface of the brown crust, or perhaps a few barnacles with their cones protruding through the sheet of plant tissue, opening their doors to sweep the water for food. But whenever I have brought a sample of this brown seaweed to my microscope, I have found it teeming with life. Always there have been many cylindrical tubes, needle-fine, built of a muddy substance. The architect of each is a small worm whose body is formed of a series of eleven infinitely small rings or segments, like eleven counters in a game of checkers, piled one above another. From its head arises a structure that makes this otherwise drab worm beautiful—a fanlike crown or plume composed of the finest feathery filaments. The filaments

absorb oxygen and also serve to ensnare small food organisms when thrust out of the tube. And always, among this microfauna of the Ralfsia crust, there have been little fork-tailed crustaceans with glittering eyes the color of rubies. Other crustaceans called ostracods are enclosed in flattened, peach-colored shells fashioned of two parts, like a box with its lid; from the shell long appendages may be thrust out to row the creatures through the water. But most numerous of all are the minute worms hurrying across the crust—segmented bristle worms of many species and smooth-bodied, serpent-like ribbon worms or nemerteans, their appearance and rapid movements betraying their predatory errands.

A pool need not be large to hold beauty within pellucid depths. I remember one that occupied the shallowest of depressions; as I lay outstretched on the rocks beside it I could easily touch its far shore. This miniature pool was about midway between the tide lines, and for all I could see it was inhabited by only two kinds of life. Its floor was paved with mussels. Their shells were a soft color, the misty blue of distant mountain ranges, and their presence lent an illusion of depth. The water in which they lived was so clear as to be invisible to my eyes; I could detect the interface between air and water only by the sense of coldness on my fingertips. The crystal water was filled with sunshine—an infusion and distillation of light that reached down and surrounded each of these small but resplendent shellfish with its glowing radiance.

The mussels provided a place of attachment for the only other visible life of the pool. Fine as the finest threads, the basal stems of colonies of hydroids traced their almost invisible lines across the mussel shells. The hydroids belonged to the group called Sertularia, in which each individual of the colony and all the supporting and connecting branches are enclosed within transparent sheaths, like a tree in winter wearing a sheath of ice. From the basal stems erect branches arose, each branch

the bearer of a double row of crystal cups within which the tiny beings of the colony dwelt. The whole was the very embodiment of beauty and fragility, and as I lay beside the pool and my lens brought the hydroids into clearer view they seemed to me to look like nothing so much as the finest cut glass—perhaps the individual segments of an intricately wrought chandelier. Each animal in its protective cup was something like a very small sea anemone—a little tubular being surmounted by a crown of tentacles. The central cavity of each communicated with a cavity that ran the length of the branch that bore it, and this in turn with the cavities of larger branches and with those of the main stem, so that the feeding activities of each animal contributed to the nourishment of the whole colony.

On what, I wondered, were these Sertularians feeding? From their very abundance I knew that whatever creatures served them as food must be infinitely more numerous than the carnivorous hydroids themselves. Yet I could see nothing. Obviously their food would be minute, for each of the feeders was of threadlike diameter and its tentacles were like the finest gossamer. Somewhere in the crystal clarity of the pool my eye—or so it seemed—could detect a fine mist of infinitely small particles, like dust motes in a ray of sunshine. Then as I looked more closely the motes had disappeared and there seemed to be once more only that perfect clarity, and the sense that there had been an optical illusion. Yet I knew it was only the human imperfection of my vision that prevented me from seeing those microscopic hordes that were the

Sertularian hydroid. The smaller cups contain feeding individuals; the larger ones the medusoid generation.

prey of the groping, searching tentacles I could barely see. Even more than the visible life, that which was unseen came to dominate my thoughts, and finally the invisible throng seemed to me the most powerful beings in the pool. Both the hydroids and the mussels were utterly dependent on this invisible flotsam of the tide streams, the mussels as passive strainers of the plant plankton, the hydroids as active predators seizing and ensnaring the minute water fleas and copepods and worms. But should the plankton become less abundant, should the incoming tide streams somehow become drained of this life, then the pool would become a pool of death, both for the mussels in their shells blue as mountains and for the crystal colonies of the hydroids.

Some of the most beautiful pools of the shore are not exposed to the view of the casual passer-by. They must be searched for —perhaps in low-lying basins hidden by great rocks that seem to be heaped in disorder and confusion, perhaps in darkened recesses under a projecting ledge, perhaps behind a thick curtain of concealing weeds.

I know such a hidden pool. It lies in a sea cave, at low tide filling perhaps the lower third of its chamber. As the flooding tide returns the pool grows, swelling in volume until all the cave is water-filled and the cave and the rocks that form and contain it are drowned beneath the fullness of the tide. When the tide is low, however, the cave may be approached from the landward side. Massive rocks form its floor and walls and roof. They are penetrated by only a few openings—two near the floor on the sea side and one high on the landward wall. Here one may lie on the rocky threshold and peer through the low entrance into the cave and down into its pool. The cave is not really dark; indeed on a bright day it glows with a cool green light. The source of this soft radiance is the sunlight that enters through the openings low on the floor of the pool, but only after its entrance into the pool does the light itself become transformed, invested with a living color of purest, palest green

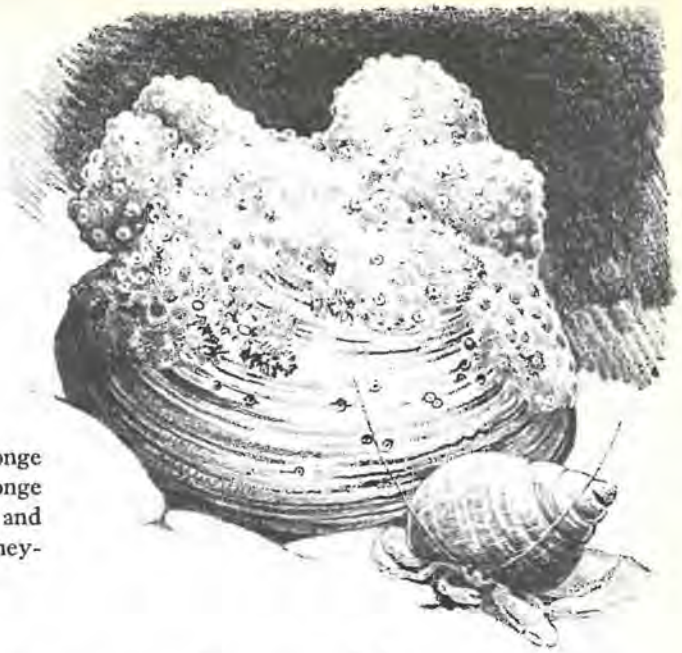
that is borrowed from the covering of sponge on the floor of the cave.

Through the same openings that admit the light, fish come in from the sea, explore the green hall, and depart again into the vaster waters beyond. Through those low portals the tides ebb and flow. Invisibly, they bring in minerals—the raw materials for the living chemistry of the plants and animals of the cave. They bring, invisibly again, the larvae of many sea creatures—drifting, drifting in their search for a resting place. Some may remain and settle here; others will go out on the next tide.

Looking down into the small world confined within the walls of the cave, one feels the rhythms of the greater sea world beyond. The waters of the pool are never still. Their level changes not only gradually with the rise and fall of the tide, but also abruptly with the pulse of the surf. As the backwash of a wave draws it seaward, the water falls away rapidly; then with a sudden reversal the inrushing water foams and surges upward almost to one's face.

On the outward movement one can look down and see the floor, its details revealed more clearly in the shallowing water. The green crumb-of-bread sponge covers much of the bottom of the pool, forming a thick-piled carpet built of tough little feltlike fibers laced together with glassy, double-pointed needles of silica—the spicules or skeletal supports of the sponge. The green color of the carpet is the pure color of chlorophyll, this plant pigment being confined within the cells of an alga that are scattered through the tissues of the animal host. The sponge clings closely to the rock, by the very smoothness and flatness of its growth testifying to the streamlining force of heavy surf. In quiet waters the same species sends up many projecting cones; here these would give the turbulent waters a surface to grip and tear.

Interrupting the green carpet are patches of other colors, one a deep, mustard yellow, probably a growth of the sulphur



Sulphur or boring sponge on clam shell. Sponge larvae bore into shells and spread until shell is honeycombed.

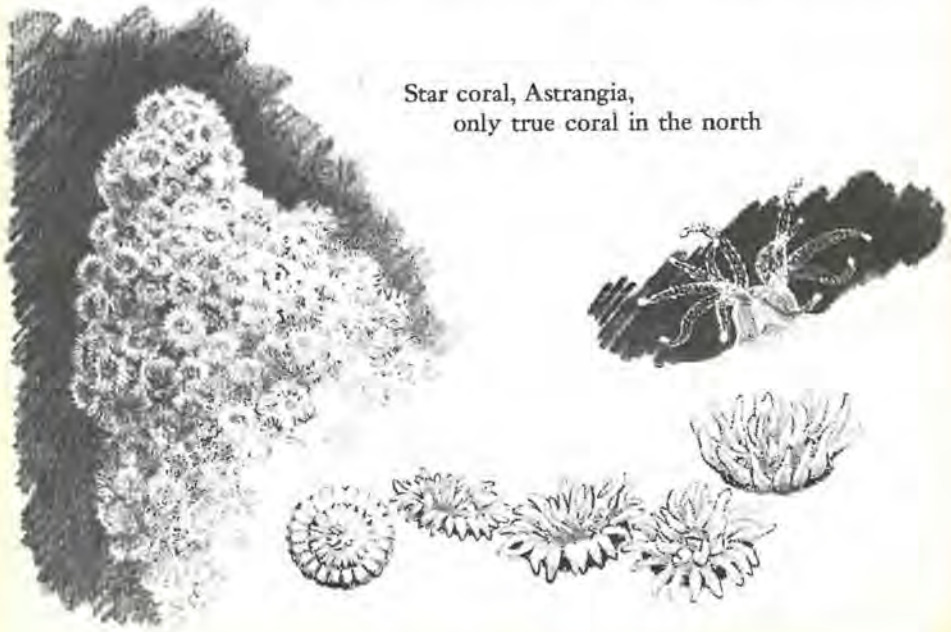
sponge. In the fleeting moment when most of the water has drained away, one has glimpses of a rich orchid color in the deepest part of the cave—the color of the encrusting coralline algae.

Sponges and corallines together form a background for the larger tide-pool animals. In the quiet of ebb tide there is little or no visible movement even among the predatory starfish that cling to the walls like ornamental fixtures painted orange or rose or purple. A group of large anemones lives on the wall of the cave, their apricot color vivid against the green sponge. Today all the anemones may be attached on the north wall of the pool, seemingly immobile and immovable; on the next spring tides when I visit the pool again some of them may have shifted over to the west wall and there taken up their station, again seemingly immovable.

There is abundant promise that the anemone colony is a thriving one and will be maintained. On the walls and ceiling of the cave are scores of baby anemones—little glistening mounds of

soft tissue, a pale, translucent brown. But the real nursery of the colony seems to be in a sort of antechamber opening into the central cave. There a roughly cylindrical space no more than a foot across is enclosed by high perpendicular rock walls to which hundreds of baby anemones cling.

On the roof of the cave is written a starkly simple statement of the force of the surf. Waves entering a confined space always concentrate all their tremendous force for a driving, upward leap; in this manner the roofs of caves are gradually battered away. The open portal in which I lie saves the ceiling of this cave from receiving the full force of such upward-leaping waves; nevertheless, the creatures that live there are exclusively a heavy-surf fauna. It is a simple black and white mosaic—the black of mussel shells, on which the white cones of barnacles are growing. For some reason the barnacles, skilled colonizers of surf-swept rocks though they be, seem to have been unable to get a foothold directly on the roof of the cave. Yet the mussels have done so. I do not know how this happened but I can guess. I can imagine the young mussels creeping in over the damp rock while the tide is out, spinning their silk threads that bind them securely, anchoring them against the returning



Star coral, Astrangia,
only true coral in the north

waters. And then in time, perhaps, the growing colony of mussels gave the infant barnacles a foothold more tenable than the smooth rock, so that they were able to cement themselves to the mussel shells. However it came about, that is the way we find them now.

As I lie and look into the pool there are moments of relative quiet, in the intervals when one wave has receded and the next has not yet entered. Then I can hear the small sounds: the sound of water dripping from the mussels on the ceiling or of water dripping from seaweeds that line the walls—small, silver splashes losing themselves in the vastness of the pool and in the confused, murmurous whisperings that emanate from the pool itself—the pool that is never quite still.

Then as my fingers explore among the dark red thongs of the dulse and push away the fronds of the Irish moss that cover the walls beneath me, I begin to find creatures of such extreme delicacy that I wonder how they can exist in this cave when the brute force of storm surf is unleashed within its confined space.

Adhering to the rock walls are thin crusts of one of the bryozoans, a form in which hundreds of minute, flask-shaped cells of a brittle structure, fragile as glass, lie one against another in regular rows to form a continuous crust. The color is a pale apricot; the whole seems an ephemeral creation that would crumble away at a touch, as hoarfrost before the sun.

A tiny spiderlike creature with long and slender legs runs about over the crust. For some reason that may have to do with its food, it is the same apricot color as the bryozoan carpet beneath it; the sea spider, too, seems the embodiment of fragility.

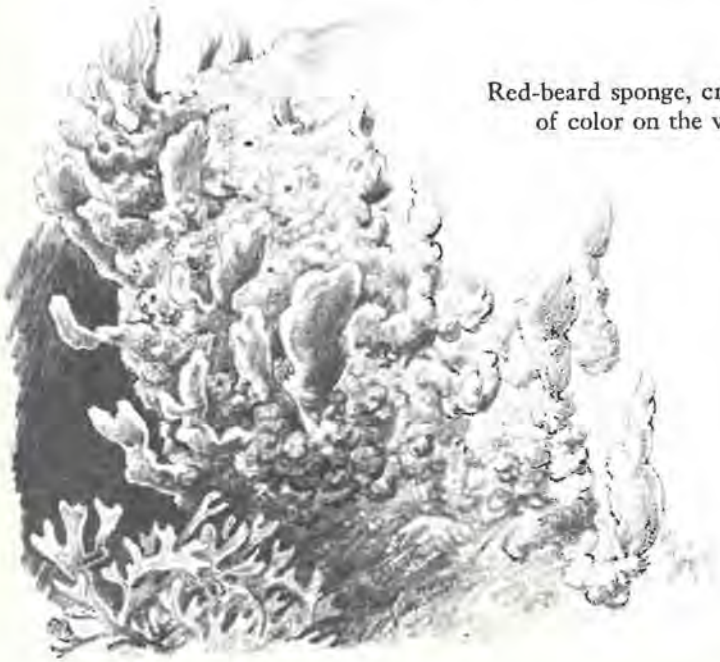
Another bryozoan of coarser, upright growth, Flustrella, sends up little club-shaped projections from a basal mat. Again, the lime-impregnated clubs seem brittle and glassy. Over and among them, innumerable little roundworms crawl with serpentine motion, slender as threads. Baby mussels creep in their tentative

exploration of a world so new to them they have not yet found a place to anchor themselves by slender silken lines.

Exploring with my lens, I find many very small snails in the fronds of seaweed. One of them has obviously not been long in the world, for its pure white shell has formed only the first turn of the spiral that will turn many times upon itself in growth from infancy to maturity. Another, no larger, is nevertheless older. Its shining amber shell is coiled like a French horn and, as I watch, the tiny creature within thrusts out a bovine head and seems to be regarding its surroundings with two black eyes, small as the smallest pinpoints.

But seemingly most fragile of all are the little calcareous sponges that here and there exist among the seaweeds. They form masses of minute, upthrust tubes of vase-like form, none more than half an inch high. The wall of each is a mesh of fine threads—a web of starched lace made to fairy scale.

I could have crushed any of these fragile structures between my fingers—yet somehow they find it possible to exist here, amid the surging thunder of the surf that must fill this cave as



Red-beard sponge, crimson spots of color on the walls of tide pools

the sea comes in. Perhaps the seaweeds are the key to the mystery, their resilient fronds a sufficient cushion for all the minute and delicate beings they contain.

But it is the sponges that give to the cave and its pool their special quality—the sense of a continuing flow of time. For each day that I visit the pool on the lowest tides of the summer they seem unchanged—the same in July, the same in August, the same in September. And they are the same this year as last, and presumably as they will be a hundred or a thousand summers hence.

Simple in structure, little different from the first sponges that spread their mats on ancient rocks and drew their food from a primordial sea, the sponges bridge the eons of time. The green sponge that carpets the floor of this cave grew in other pools before this shore was formed; it was old when the first creatures came out of the sea in those ancient eras of the Paleozoic, 300 million years ago; it existed even in the dim past before the first fossil record, for the hard little spicules—all that remains when the living tissue is gone—are found in the first fossil-bearing rocks, those of the Cambrian period.

So, in the hidden chamber of that pool, time echoes down the long ages to a present that is but a moment.

As I watched, a fish swam in, a shadow in the green light, entering the pool by one of the openings low on its seaward wall. Compared with the ancient sponges, the fish was almost a symbol of modernity, its fishlike ancestry traceable only half as far into the past. And I, in whose eyes the images of the two were beheld as though they were contemporaries, was a mere newcomer whose ancestors had inhabited the earth so briefly that my presence was almost anachronistic.

As I lay at the threshold of the cave thinking those thoughts, the surge of waters rose and flooded across the rock on which I rested. The tide was rising.

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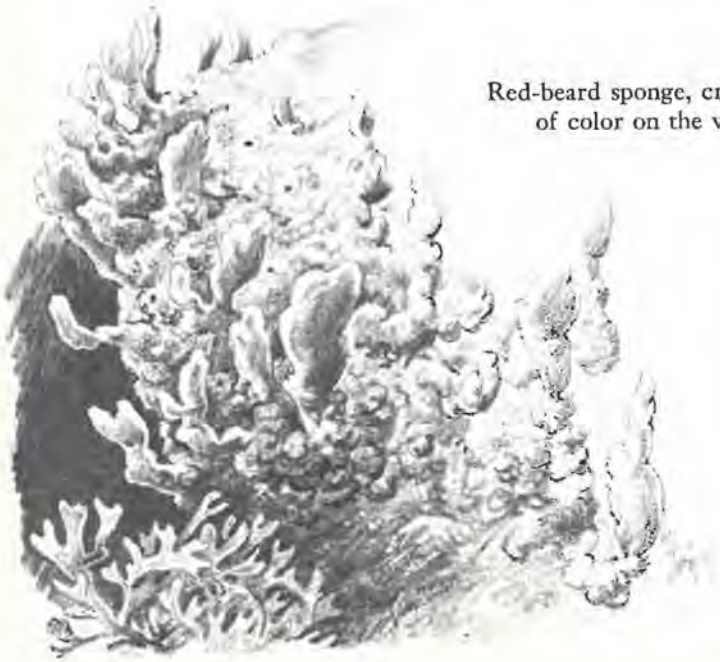

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Channeled whelk; its egg capsules are sharp-edged; those of knobbed whelk have a broad edge.

gulls visit the shoal in numbers. They have no great claws to crush the shells of their victims, but some inherited wisdom has taught them another device. Finding an exposed whelk, a gull seizes it and carries it aloft. It seeks a paved road, a pier, or even the beach itself, soars high into the air and drops its prey, instantly following it earthward to recover the treasure from among the shattered bits of shell.

Coming back over the shoal, I saw spiraling up out of the sand, over the edge of a green undersea ravine, a looped and twisted strand—a tough string of parchment on which were threaded many scores of little purse-shaped capsules. This was the egg string of a female whelk, for it was June, and the spawning time of the species. In all the capsules, I knew, the mysterious forces of creation were at work, making ready thousands of baby whelks, of which perhaps hundreds would survive to emerge from the thin round door in the wall of each capsule, each a tiny being in a miniature shell like that of its parents.

Where the waves roll in from the open Atlantic, with no outlying islands or curving arm of land to break the force of their attack on the beach, the area between the tide lines is a difficult one for living things. It is a world of force and

change and constant motion, where even the sand acquires some of the fluidity of water. These exposed beaches have few inhabitants, for only the most specialized creatures can live on sand amid heavy surf.

Animals of open beaches are typically small, always swift-moving. Theirs is a strange way of life. Each wave breaking on the beach is at once their friend and enemy; though it brings food, it threatens to carry them out to sea in its swirling backwash. Only by becoming amazingly proficient in rapid and constant digging can any animal exploit the turbulent surf and shifting sand for the plentiful food supplies brought in by the waves.

One of the successful exploiters is the mole crab, a surf-fisher who uses nets so efficient that they catch even microorganisms adrift in the water. Whole cities of mole crabs live where the waves are breaking, following the flood tide shoreward, retreating toward the sea on the ebb. Several times during the rising of a tide, a whole bed of them will shift its position, digging in again farther up the beach in what is probably a more favorable depth for feeding. In this spectacular mass movement, the sand area suddenly seems to bubble, for in a strangely concerted action, like the flocking of birds or the schooling of fish, the crabs all emerge from the sand as a wave sweeps over them. In the rush of turbulent water they are carried up the beach; then, as the wave's force slackens, they dig into the sand with magical ease, by means of a whirling motion of the tail appendages. With the ebbing of the tide, the crabs return toward the low-water mark, again making the journey in several stages. If by mischance a few linger until the tide has dropped below them, these crabs dig down several inches into the wet sand and wait for the return of the water.

As the name suggests, there is something mole-like in these small crustaceans, with their flattened, pawlike appendages. Their eyes are small and practically useless. Like all others who

Mole crabs

live within the sands the crabs depend less on sight than on the sense of touch, made wonderfully effective by the presence of many sensory bristles. But without the long, curling, feathery antennae, so efficiently constructed that even small bacteria become entangled in their strands, the mole crab could not survive as a fisher of the surf. In preparing to feed, the crab backs down into the wet sand until only the mouth parts and the antennae are exposed. Although it lies facing the ocean, it makes no attempt to take food from the incoming surf. Rather, it waits until a wave has spent its force on the beach and the backwash is draining seaward. When the spent wave has thinned to a depth of an inch or two, the mole crab extends its antennae into the streaming current. After "fishing" for a moment, it draws the antennae through the appendages surrounding its mouth, picking off the captured food. And again in this activity there is a curious display of group behavior, for when one crab thrusts up its antennae, all the others of the colony promptly follow its example.

It is an extraordinary thing to watch the sand come to life if one happens to be wading where there is a large colony of the crabs. One moment it may seem uninhabited. Then, in that fleeting instant when the water of a receding wave flows seaward like a thin stream of liquid glass, there are suddenly hundreds of little gnome-like faces peering through the sandy floor—beady-eyed, long-whiskered faces set in bodies so nearly the color of their background that they can barely be seen. And when, almost instantly, the faces fade back into invisibility, as

though a host of strange little troglodytes had momentarily looked out through the curtains of their hidden world and as abruptly retired within it, the illusion is strong that one has seen nothing except in imagination—that there was merely an apparition induced by the magical quality of this world of shifting sand and foaming water.

Since their food-gathering activities keep them in the edge of the surf, mole crabs are exposed to enemies from both land and water—birds that probe in the wet sand, fish that swim in with the tide, feeding in the rising water, blue crabs darting out of the surf to seize them. So the mole crabs function in the sea's economy as an important link between the microscopic food of the waters and the large, carnivorous predators.

Even though the individual mole crab may escape the larger creatures that hunt the tide lines, the span of life is short, comprising a summer, a winter, and a summer. The crab begins life as a minute larva hatched from an orange-colored egg that has been carried for months by the mother crab, one of a mass firmly attached beneath her body. As the time for hatching nears, the mother foregoes the feeding movements up and down the beach with the other crabs and remains near the zone of the low tide, so avoiding the danger of stranding her offspring on the sands of the upper beach.

When it escapes from the protective capsule of the egg, the young larva is transparent, large-headed, and large-eyed as are all crustacean young, weirdly adorned with spines. It is a creature of the plankton, knowing nothing of life in the sands. As it grows it molts, shedding the vestments of its larval life. So it reaches a stage in which, although still swimming in larval fashion with waving motions of its bristled legs, it now seeks the bottom in the turbulent surf zone, where the waves stir and loosen the sand. Toward the summer's end there is another molt, this time bringing transformation to the adult stage, with the feeding behavior of the adult crabs.

During the protracted period of larval life, many of the young mole crabs have made long coastwise journeys in the currents, so that their final coming ashore (if they have survived the voyage) may be far from the parental sands. On the Pacific coast, where strong surface currents flow seaward, Martin Johnson found that great numbers of the crab larvae are carried out over oceanic depths, doomed to certain destruction unless they chance to find their way into a return current. Because of the long larval life, some of the young crabs are carried as far as 200 miles offshore. Perhaps in the prevailing coastwise current of Atlantic shores they travel even farther.

With the coming of winter the mole crabs remain active. In the northern part of their range, where frost bites deep into the sands and ice may form on the beaches, they go out beyond the low-tide zone to pass the cold months where a fathom or more of insulating water lies between them and the wintry air. Spring is the mating season and by July most or all of the males hatched the preceding summer have died. The females carry their egg masses for several months until the young hatch; before winter all of these females have died and only a single generation of the species remains on the beach.

The only other creatures regularly at home between the tide lines of wave-swept Atlantic beaches are the tiny coquina clams. The life of the coquinas is one of extraordinary and almost ceaseless activity. When washed out by the waves, they must dig in again, using the stout, pointed foot as a spade to thrust down for a firm grip, after which the smooth shell is pulled rapidly into the sand. Once firmly entrenched, the clam pushes

Coquina clams

up its siphons. The intake siphon is about as long as the shell and flares widely at the mouth. Diatoms and other food materials brought in or stirred from the bottom by waves are drawn down into the siphon.

Like the mole crabs, the coquinas shift higher or lower on the beach in mass movements of scores or hundreds of individuals, perhaps to take advantage of the most favorable depth of water. Then the sand flashes with the brightly colored shells as the clams emerge from their holes and let the waves carry them. Sometimes other small burrowers move with the coquinas among the waves—companies of the little screw shell, Terebra, a carnivorous snail that preys on the coquina. Other enemies are sea birds. The ring-billed gulls hunt the clams persistently, treading them out of the sand in shallow water.

On any particular beach, the coquinas are transient inhabitants; they seem to work an area for the food it provides, and then move on. The presence on a beach of thousands of the beautifully variegated shells, shaped like butterflies and crossed by radiating bands of color, may mark only the site of a former colony.

Being only briefly and sporadically possessed by the sea in those recurrent periods of the tides' farthest advance, the high-tide zone on any shore has in its own nature something of the land as well as of the sea. This intermediate, transitional quality pervades not only the physical world of the upper beach but also its life. Perhaps the ebb and flow of the tides has accustomed some of the intertidal animals, little by little, to living out of water; perhaps this is the reason there are among the inhabitants of this zone some who, at this moment of their history, belong neither to the land nor entirely to the sea.

The ghost crab, pale as the dry sand of the upper beaches it inhabits, seems almost a land animal. Often its deep holes are back where the dunes begin to rise from the beach. Yet it is

not an air-breather; it carries with it a bit of the sea in the branchial chamber surrounding its gills, and at intervals must visit the sea to replenish the water. And there is another, almost symbolic return. Each of these crabs began its individual life as a tiny creature of the plankton; after maturity and in the spawning season, each female enters the sea again to liberate her young.

If it were not for these necessities, the lives of the adult crabs would be almost those of true land animals. But at intervals during each day they must go down to the water line to wet their gills, accomplishing their purpose with the least possible contact with the sea. Instead of wading directly into the water, they take up a position a little above the place where, at the moment, most of the waves are breaking on the beach. They stand sideways to the water, gripping the sand with the legs on the landward side. Human bathers know that in any surf an occasional wave will tower higher than the others and run farther up the beach. The crabs wait, as if they also know this, and after such a wave has washed over them, they return to the upper beach.

They are not always wary of contact with the sea. I have a mental picture of one sitting astride a sea-oats stem on a Virginia beach, one stormy October day, busily putting into its mouth food particles that it seemed to be picking off the stem. It munched away, intent on its pleasant occupation, ignoring the great, roaring ocean at its back. Suddenly the foam and froth of a breaking wave rolled over it, hurling the crab from the

Ghost crab

stem and sending both slithering up the wet beach. And almost any ghost crab, hard pressed by a person trying to catch it, will dash into the surf as though choosing a lesser evil. At such times they do not swim, but walk along on the bottom until their alarm has subsided and they venture out again.

Although on cloudy days and even occasionally in full sunshine the crabs may be abroad in small numbers, they are predominantly hunters of the night beaches. Drawing from the cloak of darkness a courage they lack by day, they swarm boldly over the sand. Sometimes they dig little temporary pits close to the water line, in which they lie watching for what the sea may bring them.

The individual crab in its brief life epitomizes the protracted racial drama, the evolutionary coming-to-land of a sea creature. The larva, like that of the mole crab, is oceanic, becoming a creature of the plankton once it has hatched from the egg that has been incubated and aerated by the mother. As the infant crab drifts in the currents it sheds its cuticle several times to accommodate the increasing size of its body; at each molt it undergoes slight changes of form. Finally the last larval stage, called the megalops, is reached. This is the form in which all the destiny of the race is symbolized, for it—a tiny creature alone in the sea—must obey whatever instinct drives it shoreward, and must make a successful landing on the beach. The long processes of evolution have fitted it to cope with its fate. Its structure is extraordinary when compared with like stages of closely related crabs. Jocelyn Crane, studying these larvae in various species of ghost crabs, found that the cuticle is always thick and heavy, the body rounded. The appendages are grooved and sculptured so that they may be folded down tightly against the body, each fitting precisely against the adjacent ones. In the hazardous act of coming ashore, these structural adaptations protect the young crab against the battering of the surf and the scraping of sand.

Once on the beach, the larva digs a small hole, perhaps as

Ghost crab larva, early stage (left); Megalops (right).

protection from the waves, perhaps as a shelter in which to undergo the molt that will transform it into the shape of the adult. From then on, the life of the young crab is a gradual moving up the beach. When small it digs its burrows in wet sand that will be covered by the rising tide. When perhaps half grown, it digs above the high-tide line; when fully adult it goes well back into the upper beach or even among the dunes, attaining then the farthest point of the landward movement of the race.

On any beach inhabited by ghost crabs, their burrows appear and disappear in a daily and seasonal rhythm related to the habits of the owners. During the night the mouths of the burrows stand open while the crabs are out foraging on the beach. About dawn the crabs return. Whether each goes, as a rule, to the burrow it formerly occupied or merely to any convenient one is uncertain—the habit may vary with locality, the age of the crab, and other changing conditions.

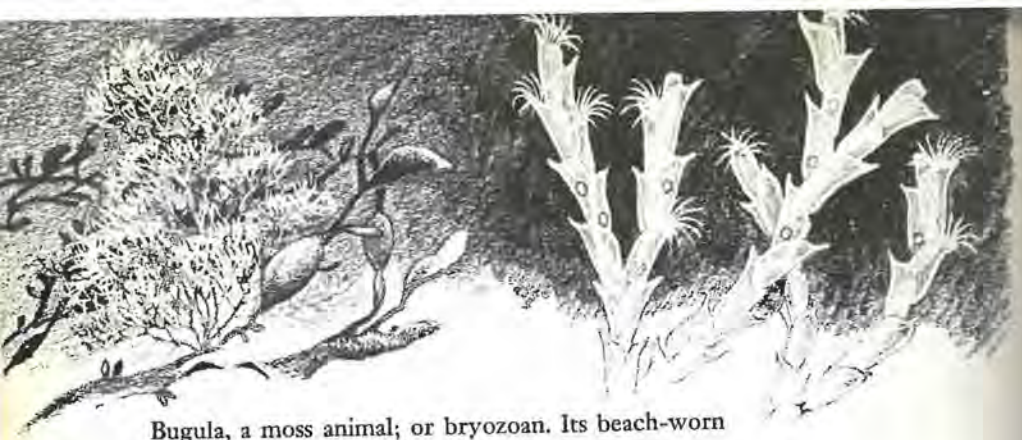
Most of the tunnels are simple shafts running down into the sand at an angle of about forty-five degrees, ending in an enlarged den. Some few have an accessory shaft leading up from the chamber to the surface. This provides an emergency exit to be used if an enemy—perhaps a larger and hostile crab—comes down the main shaft. This second shaft usually runs to the surface almost vertically. It is farther away from the water

than the main tunnel, and may or may not break through the surface of the sand.

The early morning hours are spent repairing, enlarging, or improving the burrow selected for the day. A crab hauling up sand from its tunnel always emerges sideways, its load of sand carried like a package under the legs of the functional rear end of the body. Sometimes, immediately on reaching the burrow mouth, it will hurl the sand violently away and flash back into the hole; sometimes it will carry it a little distance away before depositing it. Often the crabs stock their burrows with food and then retire into them; nearly all crabs close the tunnel entrances about midday.

All through the summer the occurrence of holes on the beach follows this diurnal pattern. By autumn most of the crabs have moved up to the dry beach beyond the tide; their holes reach deeper into the sand as though their owners were feeling the chill of October. Then, apparently, the doors of sand are pulled shut, not to be opened again until spring. For the winter beaches show no sign either of the crabs or of their holes—from dime-sized youngsters to full-grown adults, all have disappeared, presumably into the long sleep of hibernation. But, walking the beach on a sunny day in April, one will see here and there an open burrow. And presently a ghost crab in an obviously new and shiny spring coat may appear at its door and very tentatively lean on its elbows in the spring sunshine. If there is a lingering chill in the air, it will soon retire and close its door. But the season has turned, and under all this expanse of upper beach, crabs are awakening from their sleep.

Like the ghost crab, the small amphipod known as the sand hopper or beach flea portrays one of those dramatic moments of evolution, in which a creature abandons an old way of life for a new. Its ancestors were completely marine; its remote descendants, if we read its future aright, will be terrestrial. Now it is midway in the transition from a sea life to a land life.



Bugula, a moss animal; or bryozoan. Its beach-worn remains are soft plantlike tufts.

such an improbable place, one wonders how the larvae happened to be there, ready to seize the chance opportunity presented by that timber with its neatly excavated apartments; and one is struck anew by the enormous waste of life, remembering that for each of these anemones that succeeded in finding a home, many thousands must have failed.

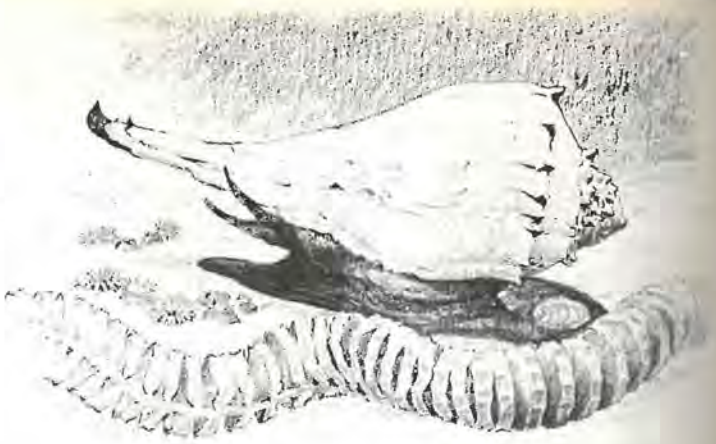
Always, then, in this flotsam and jetsam of the tide lines, we are reminded that a strange and different world lies offshore. Though what we see here may be but the husks and fragments of life, through it we are made aware of life and death, of movement and change, of the transport of living things by ocean currents, by tides, by wind-driven waves. Some of these involuntary migrants are adults. They may perish in mid-journey; a few, being transported into a new home and finding there conditions that are favorable, may survive, may even produce surviving young to extend the range of the species. But many others are larvae, and whether or not they will make a successful landing depends on many things—on the length of their larval life (can they wait for a distant landfall before they reach the stage when they must take up an adult existence?) —on the temperature of the water they encounter—on the set of the currents that may carry them to favoring shoals, or off into deep water where they will be lost.

And so, walking the beach, we become aware of a most fascinating problem—the colonization of the shore, and especially of those "islands" of rock (or the semblance of rock) that occur in the midst of a sea of sand. For whenever a seawall is built, or a jetty, or pilings are sunk for a pier or a bridge, or rock, long hidden from sun and buried even beneath the sea, emerges again on the ocean floor, these hard surfaces immediately become peopled with typical animals of the rocks. But how did the colonizing rock fauna happen to be at hand—here in the midst of a sandy coast that stretches for hundreds of miles to north and south?

Pondering the answer, we become aware of that ceaseless migration, for the most part doomed to futility, yet ensuring that always, when opportunity arises, Life shall be waiting, ready to take advantage. For the ocean currents are not merely a movement of water; they are a stream of life, carrying always the eggs and young of countless sea creatures. They have carried the hardier ones across oceans, or step by step on long coastwise journeys. They have carried some along deep, hidden passageways where cold currents flow along the floor of the ocean. They have brought inhabitants to populate new islands pushing above the surface of the sea. These things they have done, we must suppose, since first there was life in the sea.

And as long as the currents move on their courses there is the possibility, the probability, even the certainty, that some particular form of life will extend its range, will come to occupy new territory.

As almost nothing else does, this to me expresses the pressure of the life force—the intense, blind, unconscious will to survive, to push on, to expand. It is one of life's mysteries that most of the participants in this cosmic migration are doomed to failure; it is no less mysterious that their failure turns into success when, for all the billions lost, a few succeed.



Lightning or left-handed whelk

poison that may at any moment be ruptured. Apparently the fish has not developed an immunity to the poison of the holothurian. for Dr. Nigrelli found that if the cucumber was disturbed, its tenant Fierasfer would drift out in a moribund condition, even if actual evisceration did not take place.

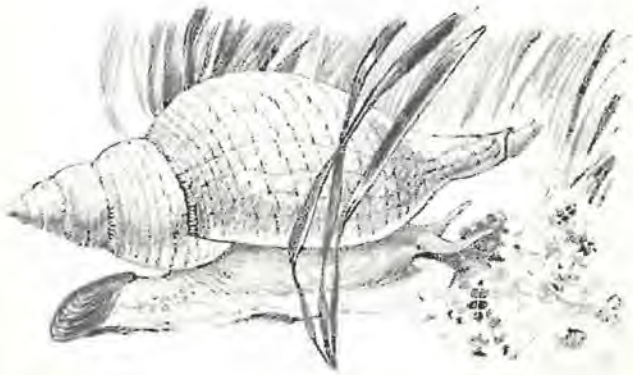
Dark patches like the shadows of clouds are scattered over the inshore shallows of the reef flats. Each is a dense growth of sea grass pushing up flat blades through the sand, forming a drowned island of shelter and security for many animals. About the Keys these grass patches consist largely of stands of turtle grass, with which manatee grass and shoal grass may be intermingled. All belong to the highest group of plants—the seed plants—and so are different from the algae or seaweeds. The algae are the earth's oldest plants, and they have always belonged to the sea or the fresh waters. But the seed plants originated on land only within the past 60 million years or so and those now living in the sea are descended from ancestors who returned to it from the land —how or why it is hard to say. Now they live where the salt sea covers them and rises above them. They open their flowers under the water; their pollen is water-borne; their seeds mature and fall and are carried away by the tide. Thrusting down their roots into the sand and the shifting coral debris, the sea grasses achieve

a firmer attachment than the rootless algae do; where they grow thickly they help to secure the offshore sands against the currents, as on land the dune grasses hold the dry sands against the winds.

In the islands of turtle grass many animals find food and shelter. The giant starfish, Oreaster, lives here. So do the large pink or queen conch, the fighting conch, the tulip band shell, the helmet shells and the cask shells. A strange, armor-encased fish, the cowfish, swims just above the bottom, parting grass blades to which pipefish and sea horses cling. Baby octopuses hide among the roots and when pursued dive down deep into the yielding sand and disappear from view. Down in that grass-root under-turf many other small beings, of diverse kinds, live deep within the shadowed coolness, to come out only when night and darkness hide them.

But by day many of the bolder inhabitants may be seen by one who wades to the grassy patches and peers down through the clarifying glass of a water telescope, or, swimming above the deeper patches, looks down through a face mask. Here one is most apt to find, in life, the large mollusks that are familiar because their dead and empty shells are common on the beach or in shell collections.

Here in the grass is the queen conch, which in earlier days had a place on almost every Victorian mantel or hearth, and even today is displayed by the hundred at every Florida roadside stand selling tourist souvenirs. Through excessive fishing,



Tulip shell

however, it is becoming rare in the Florida Keys and is now exported from the Bahamas for use in cutting cameos. The weight and massiveness of its shell, the sharp spire and the heavily armored whorls are eloquent of the defenses raised, through the slow interaction of biology and environment, by myriad ancestral generations. Despite the cumbrous shell and the massive body that thrusts itself out to move over the bottom by grotesque leaps and tumblings, the queen conch seems an alert and sentient creature. Perhaps this effect is heightened by the eyes borne on the tips of two long tubular tentacles. The way the eyes are moved and directed leaves little doubt that they receive impressions of the animal's surroundings and transmit them to the nerve centers that serve in place of a brain.

Although its strength and awareness seem to fit the queen conch for a predatory life, it is probably a scavenger that only occasionally turns to live prey. Its enemies must be comparatively few and ineffectual, but the conch has formed one very curious association. A small fish habitually lives within its mantle cavity. There can be little free space when all of the body and foot are drawn into the shell, but somehow there is room for the cardinal fish, an inch-long creature. Whenever danger threatens, it darts into the fleshy cavern deep within the shell of the conch. There it is temporarily imprisoned when the snail pulls back into its shell and closes the sickle-shaped operculum.

Queen or pink conch

To other, smaller beings that find their way into the interior of the shell, the conch reacts less tolerantly. Current-borne eggs of many sea creatures, larvae of marine worms, minute shrimp or even fish, or non-living particles like grains of sand, may swim or drift inside and, lodging on shell or mantle, set up an irritation. To this the conch responds with ancient defenses, acting to wall off the particle so that it can no longer irritate delicate tissues. The glands of the mantle secrete about this nucleus of foreign matter layer after layer of mother-of-pearl—the same lustrous substance that lines the inside of the shell. In this way the conch creates the pink pearls sometimes found within it.

The human swimmer drifting idly above the turtle grass—if he is patient enough and observant enough—may see something of other lives being lived above the coral sand, from which the thin flat blades of grass reach upward and sway to the motion of the water, leaning shoreward on a flooding tide and seaward on the ebb. If, for example, he looks very carefully he may see what he had thought to be a blade of grass (so perfectly did it simulate one by form and color and movement) detach itself from the sand and go swimming through the water. The pipefish—an incredibly long, slender, and bony-ringed creature that seems quite unfishlike—swims between the grasses slowly and with deliberate movement, now with its body held vertically, now leaning horizontally into the water. The slim head with its long, bony snout is thrust with probing motions into clusters of turtle grass leaves or down among the roots, as the fish searches for small food animals. Suddenly there is a quick, inflating motion of the cheek, and a tiny crustacean is sucked in through the tube-like beak, as one would suck a soda through a straw.

The pipefish begins life in a strange manner, being developed, nurtured, and reared beyond the stage of helpless infancy by the male parent, who keeps his young within a protective pouch. During the mating act of the pair, the ova are fertilized and

are placed in this pouch by the female; there they develop and hatch, and to this marsupium the young may return again and again in moments of danger, even long after they are able to swim out into the sea at will.

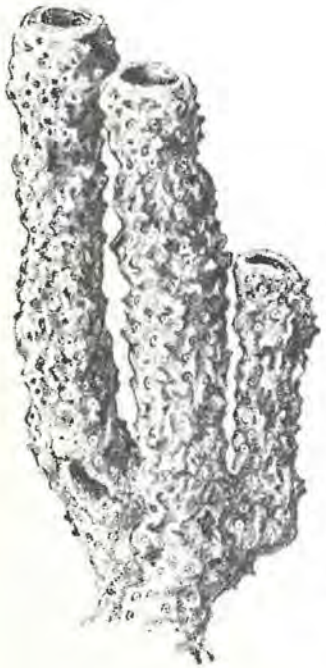
So effective is the camouflage of another inhabitant of the grass—the sea horse—that only the sharpest eye can detect one at rest, its flexible tail gripping a blade of grass and its bony little body leaning out into the currents like a piece of vegetation. The sea horse is completely encased in an armor composed of interlocking bony plates; these take the place of ordinary scales and seem to be a sort of evolutionary harking back to the time when fish depended on heavy armor to protect them from their enemies. The edges of the plates, where they join and

Horse conch, octopus, pipefish, sea horses, sea hare, giant starfish, and cowfish

interlock, are produced into ridges, knobs, and spines to form the characteristic surface pattern.

Sea horses often live in vegetation that is floating rather than rooted; such individuals may then become part of that steady northward drift bearing plants, associated animals, and the larvae of countless sea forms into the open Atlantic and eastward toward Europe, or into the Sargasso Sea. Such sea-horse voyagers in the Gulf Stream sometimes are carried ashore on the southern Atlantic coast along with bits of wind- and current-borne sargassum weed to which they cling.

In some of the turtle-grass jungles all of the smaller inhabitants seem to borrow a protective color from their surroundings. I have dragged a small dredge in such a place and found, en-



Tube sponge

The Enduring Sea

Now I HEAR the sea sounds about me; the night high tide is rising, swirling with a confused rush of waters against the rocks below my study window. Fog has come into the bay from the open sea, and it lies over water and over the land's edge, seeping back into the spruces and stealing softly among the juniper and the bayberry. The restive waters, the cold wet breath of the fog, are of a world in which man is an uneasy trespasser; he punctuates the night with the complaining groan and grunt of a foghorn, sensing the power and menace of the sea.

Hearing the rising tide, I think how it is pressing also against other shores I know—rising on a southern beach where there is no fog, but a moon edging all the waves with silver and touching the wet sands with lambent sheen, and on a still more distant shore sending its streaming currents against the moonlit pinnacles and the dark caves of the coral rock.

Then in my thoughts these shores, so different in their nature and in the inhabitants they support, are made one by the unifying touch of the sea. For the differences I sense in this particular instant of time that is mine are but the differences of a moment, determined by our place in the stream of time and in the long rhythms of the sea. Once this rocky coast beneath me was a plain of sand; then the sea rose and found a new shore line. And again in some shadowy future the surf will have ground these rocks to sand and will have returned the coast to its earlier state. And so in my mind's eye these coastal forms merge and blend

in a shifting, kaleidoscopic pattern in which there is no finality, no ultimate and fixed reality—earth becoming fluid as the sea itself.

On all these shores there are echoes of past and future: of the flow of time, obliterating yet containing all that has gone before; of the sea's eternal rhythms—the tides, the beat of surf, the pressing rivers of the currents—shaping, changing, dominating; of the stream of life, flowing as inexorably as any ocean current, from past to unknown future. For as the shore configuration changes in the flow of time, the pattern of life changes, never static, never quite the same from year to year. Whenever the sea builds a new coast, waves of living creatures surge against it, seeking a foothold, establishing their colonies. And so we come to perceive life as a force as tangible as any of the physical realities of the sea, a force strong and purposeful, as incapable of being crushed or diverted from its ends as the rising tide.

Contemplating the teeming life of the shore, we have an uneasy sense of the communication of some universal truth that lies just beyond our grasp. What is the message signaled by the hordes of diatoms, flashing their microscopic lights in the night sea? What truth is expressed by the legions of the barnacles, whitening the rocks with their habitations, each small creature within finding the necessities of its existence in the sweep of the surf? And what is the meaning of so tiny a being as the transparent wisp of protoplasm that is a sea lace, existing for some reason inscrutable to us—a reason that demands its presence by the trillion amid the rocks and weeds of the shore? The meaning haunts and ever eludes us, and in its very pursuit we approach the ultimate mystery of Life itself.

Appendix: Classification

Protophyta, Protozoa: One-celled Plants and Animals

THE SIMPLEST FORMS of cellular life are the one-celled plants (Protophyta) and one-celled animals (Protozoa). In both groups, however, there are many forms that defy attempts to place them definitely in one category or another because they display characteristics usually considered animal-like along with others usually thought definitive of plants. The *Dinoflagellata* form such an indeterminate group, and are claimed both by zoologists and by botanists. Although a few are large enough to be seen without magnification, most are smaller. Some wear shells with spines and elaborate markings. Some have a remarkable, eye-like sense organ. All dinoflagellates are immensely important in the economy of the sea as food for certain fishes and other animals. Noctiluca is a relatively large dinoflagellate of coastal waters, where it produces brilliant displays of phosphorescence, or by day reddens the water by the abundance of its pigmented cells. Other species are the cause of the phenomenon known as "red tide," in which the sea is discolored and fishes and other animals die from poisons given off by the minute cells. The red or green scum of high tide pools, "red rain," and "red snow" are growths of these forms, or of green algae (e.g., Sphaerella). Much phosphorescence or "burning" of the sea is caused by dinoflagellates, which create a uniformly diffused light, lacking large spots of illumination. Examined closely, in a vessel of water, the light is seen to consist of tiny sparks.

Sphaerella

The *Radiolaria* are one-celled animals whose pro-

Dinoflagellates