range or such-like divide, and not on the other. A warm ocean current like the Gulf Stream may be deflected, and flow so as to warm one side of the barrier, leaving the other still cold. Then on the cold side this species will still be going on to its utmost possible furriness and whiteness, and on the other side it will be modifying towards brownness and a thinner coat.

At the same time there will probably be other changes going on; a difference in the paws perhaps may be encouraged here and discouraged there, because one half of the species will be frequently scratching through snow for its food, while the other will be scampering over brown earth. Probably, also, the difference of climate will mean differences in the sort of food available, and that may favour differences in the teeth and the digestive organs. And there may be changes in the sweat and oil glands of the skin due to the changes in the fur, and these will affect the excretory organs and all the internal chemistry of the body. And so through all the structure of the creature. A time may come when the two separated varieties of this formerly single species may become so unlike each other through the accumulation of individual and mutational differences as to be recognizably different species. Such a splitting up of a species in the course of generations into two or more species is called the *Differentiation of Species.*

And it should be clear to the reader that, given these elemental facts of life, given growth and death and reproduction with individual variation and mutation in a world that changes, life *must* change in this way, modification and differentiation *must* occur, old species *must* disappear and new ones appear. We have chosen for our instance here a familiar sort of animal, but what is true of furry beasts in snow and ice is true of all life, and equally true of the soft jellies and simple beginnings that flowed and crawled for hundreds of millions of years between the tidal levels and in the shallow, warm waters of the Proterozoic seas. They were all varying and mutating and living in a world of change that encouraged many of their variations and mutations.

The early life of the early world, when the blazing sun rose and set in only a quarter of the time it now takes, when the warm seas poured in great tides over the sandy and muddy shores of the rocky lands and the air was full of clouds and steam, must have been modified and varied, and species must have developed, at a great pace. Life was probably as swift and short as the days and years; the generations, which natural selection picked over, followed one another in rapid succession.

Natural selection is a slower process with man than with any other creature. It takes twenty years or more before an ordinary western European grows up and reproduces. In the case of most animals the new generation is on trial in a year or less. With such simple and lowly beings, however, as first appeared in the primordial seas, growth and reproduction was probably a matter of a few brief hours or even of a few brief minutes. Modification and differentiation of species must accordingly have been extremely rapid, and life had already developed a great variety of widely contrasted forms before it began to leave traces in the rocks.

The Record of the Rocks does not begin, therefore, with any group of the closely related forms from which all subsequent and existing creatures are descended. It begins in the Sea, with nearly every main division of the animal kingdom already represented. Plants are already plants, and animals animals.

The brachiopods are already in their shells, consuming much the same sort of food that oysters and mussels do now; the great water-scorpions crawl among the seaweeds, the trilobites roll up into balls and unroll and scuttle away. In that ancient mud there was probably as rich a life of infusoria and the like as one finds in a drop of ditch-water to-day. In the ocean there was an abundance of minute and translucent, often phosphorescent, beings.

But the land above the high-tide line was still, so far as we can guess, a stony wilderness without a trace of life.

CHAPTER 3

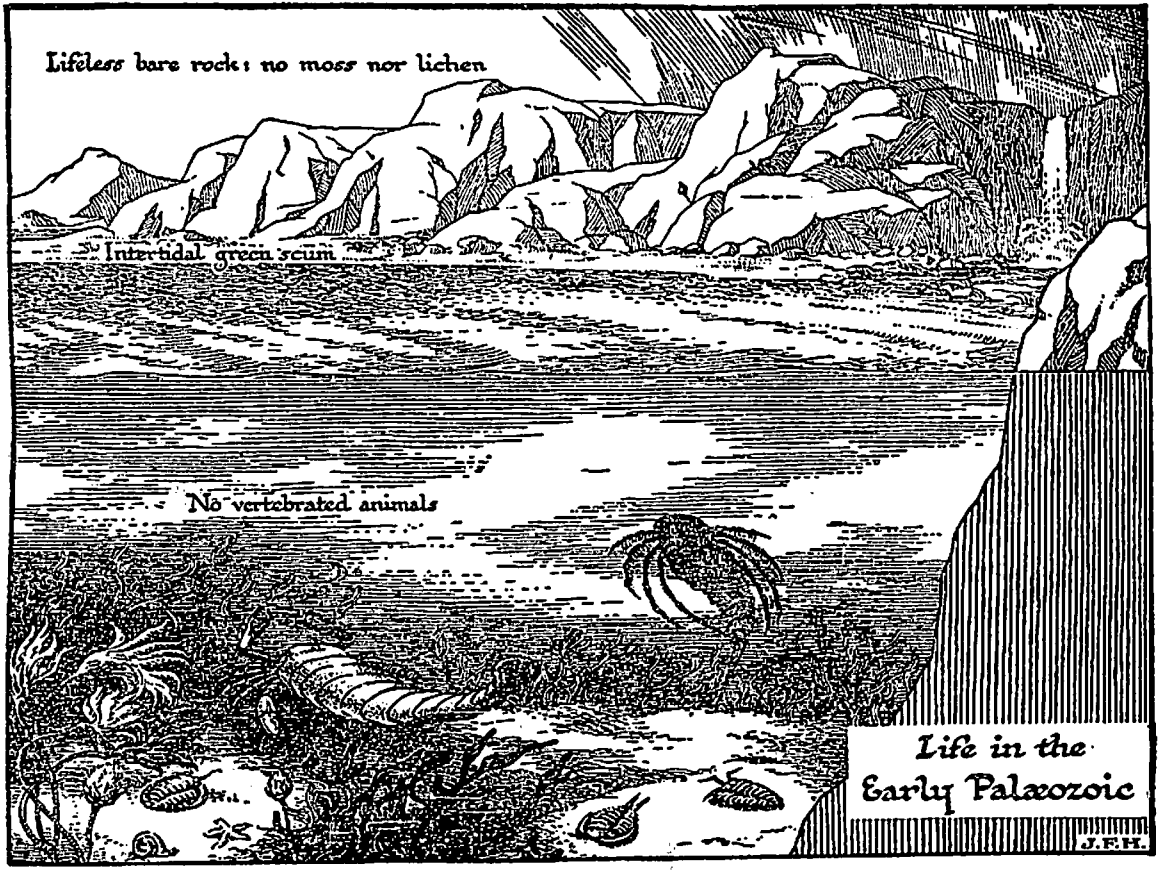
LIFE AND CLIMATE

§ 1

WHEREVER the shore line ran there was life, and that life went on in and by and with water as its home, its medium, and its fundamental necessity.

The first jelly-like beginnings of life must have perished whenever they got out of the water, as jelly-fish dry up and perish on our beaches to-day. Drying up was the fatal thing for life in those days, against which at first it had no protection. But in a world of rain-pools and shallow seas and tides, any variation that enabled a living thing to hold out and keep its moisture during hours of low tide or drought met with every encouragement in the circumstances of the time. There must have been a constant risk of stranding. And, on the other hand, life had to keep rather near the shore and beaches in the shallows because it had need of air (dissolved, of course, in the water) and light.

No creature can breathe, no creature can digest its food, without water. We talk of breathing air, but what all living things really do is to breathe oxygen dissolved in water. The air we ourselves breathe must first be dissolved in the moisture in our lungs: and all our food must be liquefied before it can be assimilated. Water-living creatures which are always under water, wave the freely exposed gills by which they breathe in that water, and extract the air dissolved in it. But a creature that is to be exposed for any time out of the water must have its body and its breathing apparatus protected from drying up. Before the seaweeds could creep up out of the Early Palæozoic seas into the intertidal line of the beach, they had to develop a tougher outer skin to hold their moisture. Before the ancestor of the sea-scorpion could survive being left by the tide, it had to develop its casing and armour. The trilobites probably



Note its general resemblance, except for size, to the microscopic summer ditchwater life of to-day

developed their tough covering and rolled up into balls far less as a protection against each other, and any other enemies they may have possessed, than as a precaution against drying. And when presently, as we ascend the Palæozoic rocks, the fish appear, first of all the backboned or vertebrated animals, it is evident that a number of them are already adapted, by the protection of their gills with gill covers, and by a sort of primitive lung swimming-bladder, to face the same risk of temporary stranding.

Now, the weeds and plants that were adapting themselves to intertidal conditions were also bringing themselves into a region of brighter light; and light is very necessary and precious to all plants. Any development of structure that would stiffen them and hold them up to the light, so that instead of crumpling and flopping when the waters receded they would stand up outspread, was a great advantage. And so we find them developing fibre and support, and the beginning of *woody fibre* in them. The early plants reproduced by soft spores, or half-animal "gametes," that were released in water, were distributed by water and could only germinate under water. The early plants were tied, and most lowly plants to-day are tied, by the conditions of their life-cycle, to water. But here again there was a great advantage to be got by the development of some protection of the spores from drought that would enable reproduction to occur without submergence. So soon as a species could do that, it could live and reproduce and spread above the high-water mark, bathed in light and out of reach of the beating and distress of the waves. The main classificatory divisions of the larger plants mark stages in the release of plant life from the necessity of submergence by the development of woody support and of a method of reproduction that is more and more defiant of drying up. The lower plants are still the prisoner attendants of water. The lower mosses must live in damp, and even the development of the spore of the ferns demands at certain stages extreme wetness. The highest plants have carried freedom from water so far that they can live and reproduce if only there is some moisture in the soil below them. They have solved their problem of living out of water altogether.

The essentials of that problem were worked out through the vast æons of the Proterozoic Age and the early Palæozoic Age by nature's method of experiment and trial. Then slowly, but in great abundance, a variety of new plants began to swarm away from the sea and over the lower lands, still keeping to swamp and lagoon and watercourse as they spread.

There was not, perhaps, the same distinction between sea plants and fresh-water plants that there is to-day. The sea was probably less salt than it is now.

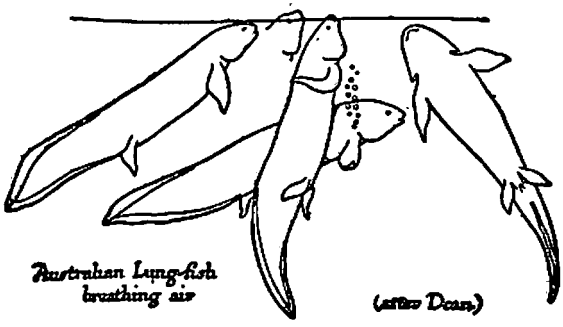
§ 2

The Earliest Land Animals.

And after the plants came the animal life.

There is no sort of land animal in the world, as there is no sort of land plant, whose structure is not primarily that of a water-inhabiting being which has been adapted through the modification and differentiation of species to life out of the water. This adaptation is attained in various ways. In the case of the land-scorpion the gill-plates of the primitive sea-scorpion are sunken into the body so as to make the lung-books secure from rapid evaporation. The gills of crustaceans, such as the crabs, which run about in the air are protected by the gill-cover extensions of the back shell or carapace. The ancestors of the insects developed a system of air pouches and air tubes, the tracheal tubes, which carry the air all over the body before it is dissolved. In the case of the vertebrated land animals, the gills of the ancestral fish were first supplemented and then replaced by a bag-like growth from the throat, the primitive lung swimming-bladder.

To this day there survive certain mudfish which enable us to understand very clearly the method by which the vertebrated land animals worked their way out of the water. These creatures (the African lung-fish, for example) are found in tropical regions in which there is a rainy full season and a dry season during which the rivers become mere ditches of baked mud. During the rainy season these fish swim about and breathe by gills like any other fish. As the waters of the river evaporate they bury themselves in the mud, their gills go out of



Australian Lung-fish breathing air (after Dean)

action, and the creature keeps itself alive, until the waters return, by swallowing air, which passes into its swimming-bladder. The Australian lung-fish, when it is caught by the drying-up of the river in stagnant pools, and the water has become deaerated and foul, rises to the surface and gulps air. A newt in a pond does exactly the same thing. These creatures still remain at the transition stage, the stage at which the ancestors of the higher vertebrated animals were released from their restriction to an under-water life.

The amphibia (frogs, newts, tritons, etc.) still show in their life-history all the stages in the process of this liberation. They are still dependent on water for their reproduction; their eggs must be laid in sunlit water, and there they must develop. The young tadpole has branching external gills that wave in the water; then a gill-cover grows back over them and forms a gill chamber. Then, as the creature's legs appear and its tail is absorbed, it begins to use its lungs, and its gills dwindle and vanish. The tadpole can live under water continually. The adult frog can live all the rest of its days in the air, but it can be drowned if it is kept steadfastly below water.

When we ascend the scale of existence to the level of the reptile, however, we find an egg which is protected from evaporation by a tough egg case, and this egg produces young which breathe by lungs from the very moment of hatching. The reptile is on all fours with the seeding plant in its freedom from the necessity to pass any stage of its life-cycle in water. But it can be drowned if it is kept under water without intermission.

The later Palæozoic rocks of the northern hemisphere give us the materials for a series of pictures of this slow spreading of life over the land. Geographically it was an age of lagoons and shallow seas very favourable to this invasion. It is possible that as yet there were no seas as deep as the present oceans. The new plants, now that they had acquired the power to live the new aerial life, developed with an extraordinary richness and variety.

There were as yet no true flowering plants, no grasses nor trees that shed their leaves in winter; the first "flora" consisted of great tree-ferns, gigantic equisetums, cycad ferns, and kindred vegetation. Many of these plants took the form of huge-stemmed trees, of which great multitudes of trunks survive fossilized to this day. Some of these trees were over a hundred feet high, they belonged to orders and classes now vanished from the world. They stood with their stems in the water, in which no doubt there was a thick tangle of soft mosses and

green slime and fungoid growths that left few plain vestiges behind them. The abundant pulped-up remains of these first swamp forests constitute the main coal-measures of the world to-day.

Amidst this luxuriant primitive vegetation crawled and glided and flew the first insects. They were rigid-winged, four-winged creatures, often very big, some of them having wings measuring a foot in length. There were numerous dragon-flies—one found in the Belgian coal-measures had a wing span of twenty-nine inches! There were also a great variety of flying cockroaches. Scorpions abounded, and a number of early spiders. The spinnerets of these spiders were absent or simple, so that they made no webs or very simple ones. Land snails appeared. So, too, did the first-known step of our own ancestry upon land, the amphibia. As we ascend the higher levels of the later Palæozoic record we find the process of air adaptation has gone as far as the appearance of true reptiles amidst the abundant and various amphibia.

The land life of the Upper Palæozoic Age was the life of an ever-green swamp forest without flowers or birds or the noises of modern insects. If a man could be transported back to those verdurous lagoons he would probably be terrified at the stillness. He would hear little but the ripple of water, the sound of wind in the leaves, or the crash of some falling tree. Everything would seem waiting and expectant. The trees and plants would look more like magnified mosses than any trees or plants he knew. There were no big land beasts at all; wallowing amphibia and primitive reptiles were the very highest creatures that life had so far produced. None of them had yet attained to very great dimensions. Whatever land lay away from the water or high above the water was still altogether barren and lifeless. But steadfastly, generation by generation, life was creeping away from the shallow sea-water of its beginning.

§ 3

Why Life Must Change Continually.

The Record of the Rocks is like a great book that has been carelessly misused. All its pages are torn, worn, and defaced, and many are altogether missing. The outline of the story that we sketch here has been pieced together slowly and painfully in an investigation that is still incomplete and still in progress. The Carboniferous rocks, the "coal-measures," give us a vision of the first great expansion of life over the wet low-