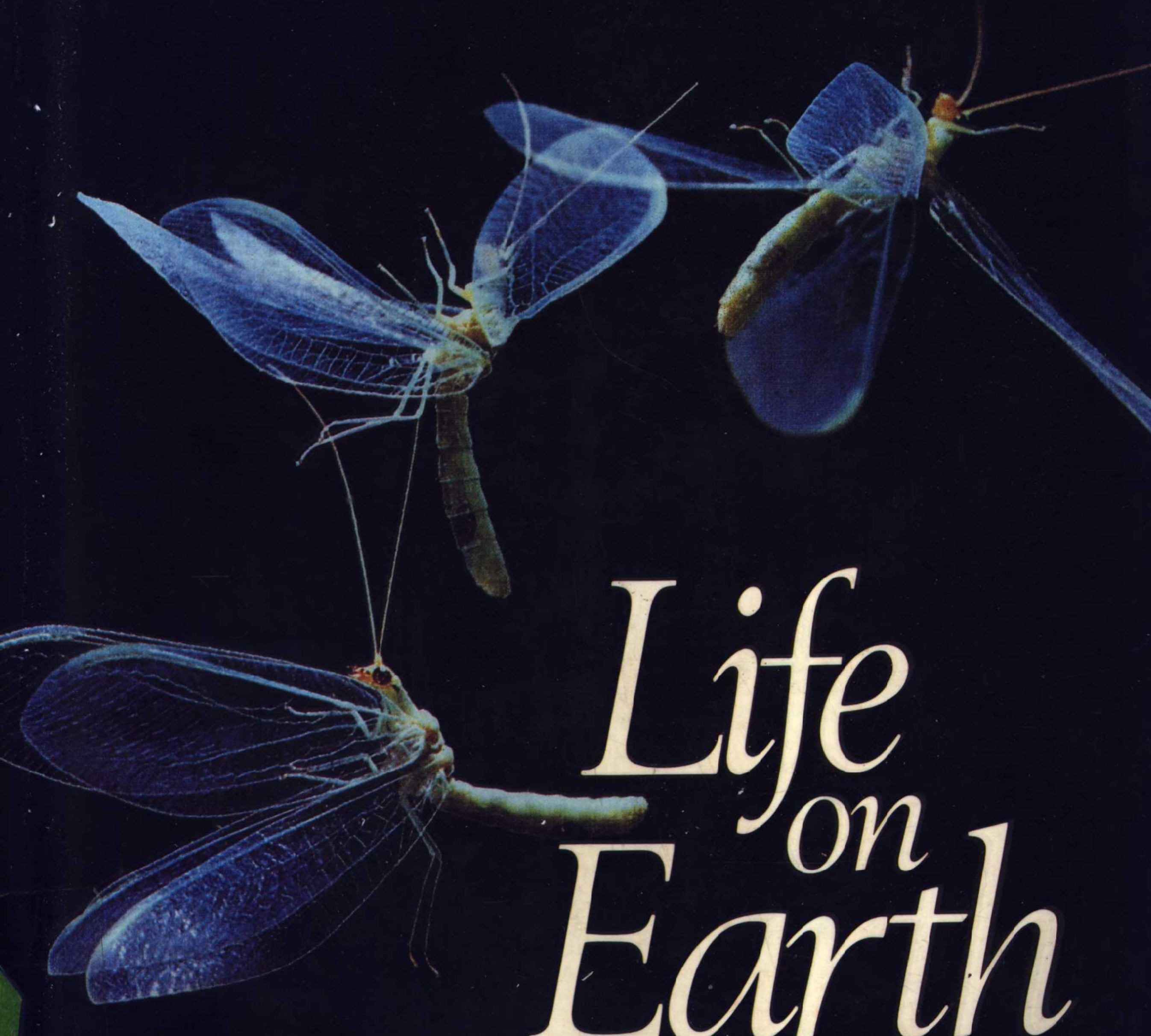
DAVID ATTENBOROUGH



Life on Earth

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A NATURAL HISTORY

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INTRODUCTION

Twenty-five years ago, I went to the tropics for the first time. I still recall, with great clarity, the shock of stepping out of the plane and into the muggy, perfumed air of West Africa. It was like walking into a steam laundry. Moisture hung in the atmosphere so heavily that my skin and shirt were soaked within minutes. A hedge of hibiscus bordered the airport buildings. Sunbirds, glittering with green and blue iridescence, played around it, darting from one scarlet blossom to another, hanging on beating wings as they probed for nectar. Only after I had watched them for some time did I notice, clasping a branch within the hedge, a chameleon, motionless except for its goggling eyes which swivelled to follow every passing insect. Beside the hedge, I trod on what appeared to be grass. To my astonishment, the leaflets immediately folded themselves flat against the stem, transforming green fronds into apparently bare twigs. It was sensitive mimosa. Beyond lay a ditch covered with floating plants. In the spaces between them, the black water wriggled with fish, and over the leaves walked a chestnut-coloured bird, lifting its long-toed feet with the exaggerated care of a man in snow-shoes. Wherever I looked, I found a prodigality of pattern and colour for which I was quite unprepared. It was a revelation of the splendour and fecundity of the natural world from which I have never recovered.

Almost every year since that first trip, I have managed, one way or another, to get back to the tropics. Usually my purpose has been to make a film about some corner of that infinitely varied world. So I have had the luck to journey for months with the sole object of finding and filming a rare creature that few people have seen in the wild, and to gaze on some of the most marvellous spectacles that the wild places of the world have to offer – a tree full of displaying birds of paradise in New Guinea, giant lemurs leaping through the forest of Madagascar, the biggest lizards in the world prowling, like dragons, through the jungle of a tiny island in Indonesia.

The films we made tried to document the lives of particular animals showing how each found its food, defended itself and courted, and the ways in which it fitted into the community of animals and plants around it. One element, however, was missing. We seldom examined the basic character of its anatomy. The quintessence of, for example, a lizard is only fully understandable in the light of the particular possibilities and limitations dictated by its reptilian nature and that, in turn, only becomes comprehensible in the light of its past.

So the idea formed that a group of us might make a series of films that portrayed animals in a slightly different way from any we had attempted before. Such films would be concerned not only with natural history in the sense that those two words are normally used, but with the history of nature. They would try to survey the whole animal kingdom and consider each great group of animals in the light of the part it has played in the long drama of life from its beginnings until today. This book stems from the three years of travelling and research that went into the making of those films.

The condensation of three thousand million years of history into three hundred pages, the description of a group of animals containing tens of thousands of species within one chapter, compels vast omissions. My method has been to try to perceive the single most significant thread in the history of a group and then concentrate on tracing that, resolutely ignoring other issues, no matter how enticing they may seem.

This, however, risks imposing an appearance of purpose on the animal kingdom that does not exist in reality. Darwin demonstrated that the driving force of evolution comes from the accumulation, over countless generations, of chance genetical changes sifted by the rigours of natural selection. In describing the consequences of this process it is only too easy to use a form of words that suggests that the animals themselves were striving to bring about change in a purposeful way – that fish *wanted* to climb on to dry land and to modify their fins into legs, that reptiles *wished* to fly, strove to change their scales into feathers and so ultimately became birds. There is no objective evidence of anything of the kind and I have endeavoured, while describing these processes in a reasonably succinct way, not to use any phrases that might suggest otherwise.

To a surprising degree, nearly all the major events in this history can be told using living animals to represent the ancestral creatures which were the actual protagonists. The lungfish today shows how lungs may have developed; the mouse deer represents the first hoofed mammals that browsed in the forests of fifty million years ago. But misunderstandings can come unless the nature of this impersonation is made quite clear. In rare instances, a living species seems to be identical with one whose remains are fossilised in rocks several hundred million years old. It happens to have occupied a niche in the environment that has existed unchanged for such vast periods of time and suited it so ideally that it had no cause to change. In most cases, however, living species, while they may share essential characters with their ancestors, differ from them in many ways. The lungfish and the mouse-deer are fundamentally similar to their ancestors, but they are by no means identical. To underline this distinction each time with a phrase like 'ancestral forms that closely resemble the living species' would be unnecessarily clumsy and literal-minded, but that qualifying phrase must be taken as read whenever I have referred to an ancient creature by the name of a living one.

I have used familiar English names rather than scientific Latin ones so that when an animal makes its appearance in this history, it is quickly recognised for what it is. Those who wish to discover more about its anatomy and biography in more technical books will find its scientific name in the index. I have expressed age in absolute terms of millions of years rather than use the adjectival names of periods coined by classical geology. The former may be converted into the latter by reference to the genealogical tree on page 310. Lastly, I have made no reference by name to those many scientists whose work has provided the facts and theories on which the following pages are based. This has been done solely to try to maintain clarity in the narrative. I intend no minimisation of the debt owed to them by all of us who take pleasure in watching animals. They and their researches have provided us with that most valuable of insights, the ability to perceive the continuity of nature in all its manifestations and to recognise our place within it.

ONE

THE INFINITE VARIETY

It is not difficult to discover an unknown animal. Spend a day in the tropical forest of South America, turning over logs, looking beneath bark, sifting through the moist litter of leaves, followed by an evening shining a mercury lamp on a white screen, and one way and another you will collect hundreds of different kinds of small creatures. Moths, caterpillars, spiders, long-nosed bugs, luminous beetles, harmless butterflies disguised as wasps, wasps shaped like ants, sticks that walk, leaves that open wings and fly – the variety will be enormous and one of these creatures will almost certainly be undescribed by science. The difficulty will be to find specialists who know enough about the groups concerned to be able to single out the new one.

No one can say just how many species of animals there are in these greenhouse-humid dimly lit jungles. They contain the richest and the most varied assemblage of animal and plant life to be found anywhere on earth. Not only are there many major categories of creatures – monkeys, rodents, spiders, hummingbirds, butterflies – but most of those types exist in many different forms. There are over forty different species of parrot, over seventy different monkeys, three hundred hummingbirds and tens of thousands of butterflies. If you are not careful, you can even be bitten by a hundred different kinds of mosquito.

In 1832 a young Englishman, Charles Darwin, twenty-four years old and naturalist on HMS *Beagle*, a brig sent by the Admiralty in London on a surveying voyage round the world, came to such a forest outside Rio de Janeiro. In one day, in one small area, he collected sixty-eight different species of small beetle. That there should be such a variety of species of one kind of creature astounded him. He had not been searching specially for them so that, as he wrote in his journal, 'It is sufficient to disturb the composure of an entomologist's mind to look forward to the future dimensions of a complete catalogue'. The conventional view of his time was that all species were immutable and that each had been individually and separately created by God. Darwin was far from being an atheist – he had, after all, taken a degree in divinity in Cambridge – but he was deeply puzzled by this enormous multiplicity of forms.

During the next three years, the *Beagle* sailed down the east coast of South America,

Marine iguanas and crabs, Galapagos

Giant tortoises, Galapagos

rounded Cape Horn and came north again up the coast of Chile. The expedition then sailed out into the Pacific until, 600 miles from the mainland, they came to the lonely archipelago of the Galapagos. Here Darwin's questions about the creation of species recurred, for in these islands he found fresh variety. He was fascinated to discover that the Galapagos animals bore a general resemblance to those he had seen on the mainland, but differed from them in detail. There were cormorants, black, long-necked diving birds like those that fly low along Brazilian rivers, but here in the Galapagos, their wings were so small and with such stunted feathers that they had lost the power of flight. There were iguanas, large lizards with a crest of scales along their backs. Those on the continent climbed trees and ate leaves. Here on the islands, where there was little vegetation, one species fed on seaweed and clung to rocks among the surging waves with unusually long and powerful claws. There were tortoises, very similar to the mainland forms except that these were many times bigger, giants that a man could ride. The English Vice-Governor of the Galapagos told Darwin that even within the archipelago, there was variety: the tortoises on each island were slightly different, so that it was possible to tell which island they came from. Those that lived on relatively well watered islands where there was ground vegetation to be cropped, had a gently curving front edge to their shells just above the neck. But those that came from arid islands and had to crane their necks in order to reach branches of cactus or leaves of trees, had much longer necks and a high peak to the front of their shells that enabled them to stretch their necks almost vertically upwards.

The suspicion grew in Darwin's mind that species were not fixed for ever. Perhaps one could change into another. Maybe, thousands of years ago, birds and reptiles from continental South America had reached the Galapagos, ferried on the rafts of vegetation that float down the rivers and out to sea. Once there, they had changed, as generation succeeded generation, to suit their new homes until they became their present species.

The differences between them and their mainland cousins were only small, but if such changes had taken place, was it not possible that over many millions of years, the cumulative effects on a dynasty of animals could be so great that they could bring about major transformations? Maybe fish had developed muscular fins and crawled on to land to become amphibians; maybe amphibians in their turn had developed water-tight skins and become reptiles; maybe, even, some ape-like creatures had stood upright and become the ancestors of man.

In truth the idea was not a wholly new one. Many others before Darwin had suggested that all life on earth was interrelated. Darwin's revolutionary insight was to perceive the mechanism that brought these changes about. By doing so he replaced a philosophical speculation with a detailed description of a process, supported by an abundance of evidence, that could be tested and verified; and the reality of evolution could no longer be denied.

Put briefly, his argument was this. All individuals of the same species are not identical. In one clutch of eggs from, for example, a giant tortoise, there will be some hatchlings which, because of their genetic constitution, will develop longer necks than others. In times of drought they will be able to reach leaves and so survive. Their brothers and sisters, with shorter necks, will starve and die. So those best fitted to their surroundings will be selected and be able to transmit their characteristics to their offspring. After a great number of generations, tortoises on the arid islands will have longer necks than those on the watered islands. And so one species will have given rise to another.

This concept did not become clear in Darwin's mind until long after he had left the Galapagos. For twenty-five years he painstakingly amassed evidence to support it. Not until 1859, when he was forty-eight years old, did he publish it and even then he was driven to do so only because another younger naturalist, Alfred Wallace, working in Southeast Asia, had formulated the same idea. He called the book in which he set out his theory in detail, *The Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life.*

Since that time, the theory of natural selection has been debated and tested, refined, qualified and elaborated. Later discoveries about genetics, molecular biology, population dynamics and behaviour have given it new dimensions. It remains the key to our understanding of the natural world and it enables us to recognise that life has a long and continuous history during which organisms, both plant and animal, have changed, generation by generation, as they colonised all parts of the world.

The direct, if fragmentary, evidence for this history lies in the archives of the earth, the sedimentary rocks. The vast majority of animals leave no trace of their existence after their passing. Their flesh decays, their shells and their bones become scattered and turn to powder. But very occasionally, one or two individuals out of a population of many thousands have a different fate. A reptile becomes stuck in a swamp and dies. Its body rots but its bones settle into the mud. Dead vegetation drifts to the bottom and covers them. As the centuries pass and more vegetation accumulates, the deposit turns to peat. Changes in sea level may cause the swamp to be flooded and layers of sand to be deposited on top of the peat. Over great periods of time, the peat is compressed and turned to coal. The reptile's bones still remain within it. The great pressure of the overlying sediments and the mineral-rich solutions that circulate through them cause chemical changes in the calcium phosphate of the bones. Eventually they are turned to stone, but they retain not only the outward shape that they had in life, albeit sometimes distorted, but on occasion even their detailed cellular structure is preserved so that you can look at sections of them through the microscope and plot the shape of the blood vessels and the nerves that once surrounded them.

The most suitable places for fossilisation are in seas and lakes where sedimentary deposits like sandstones and limestones are slowly accumulating. On land, where for the most part rocks are not built up by deposition but broken down by erosion, deposits, such as sand dunes, are only very rarely created and preserved. In consequence, the only land-living creatures likely to be fossilised are those that happen to fall into water. Since this is exceptional fate for most of them, we are never likely to know from fossil evidence anything approaching the complete range of land creatures that has existed in the past. Water-living animals, such as fish, molluscs, sea urchins and corals, are much more promising candidates for preservation. Even so, very few of these perished in the exact physical and chemical conditions necessary for fossilisation. Of those that did, only a tiny proportion happen to lie in the rocks that outcrop on the surface of the ground today; and of these few, most will be eroded away and destroyed before they are discovered by fossil hunters. The astonishment is that, in the face of these adverse odds, the fossils that have been collected are so numerous and the record they provide so detailed and coherent.

How can we date them? Since the discovery of radioactivity scientists have realised that rocks have a geological clock within them. Several chemical elements decay with age, producing radioactivity in the process. Potassium turns into argon, uranium into lead, rubidium into strontium. The rate at which this happens can be estimated. So if the proportion of the secondary element to the primary one in a rock is measured, the time at which the original mineral was formed can be calculated. Since there are several such pairs of elements decaying at different speeds, it is possible to make cross-checks. This technique, which requires extremely sophisticated methods of analysis, will always remain the province of the specialist. But anyone can date many rocks in a relative way by simple logic and by doing so put into order the major events of fossil history. If rocks lie in layers, and are not grossly disturbed, then the lower layer must be older than the upper. So we can follow the history of life through the strata and trace the lineages of animals back to their beginnings by going deeper and deeper into the earth's crust.

The deepest cleft that exists in the earth's surface is the Grand Canyon in the western United States. The rocks through which the Colorado River has cut its way still lie roughly horizontally, layer upon layer, red, brown and yellow, sometimes pink in early light, sometimes blue in the shadowed distance. The land is so dry that only isolated juniper trees and low scrub freckle the surface of the cliffs and the rock strata, some soft, some hard, are clear and stark. Most of them are sandstones or limestones that were laid down at the bottom of the shallow seas that once covered this part of North America. When they are examined closely, breaks in the succession can be detected. These represent times when the land rose, the seas drained away and the sea bed became dry so that the deposits that had accumulated on it were eroded away. Subsequently, the land sank again, seas flooded back and deposition restarted. In spite of these gaps, the broad lines of the fossil story remain clear.

A mule will carry you in an easy day's ride from the rim to the very bottom of the Canyon. The first rocks you pass are already some 200 million years old. There are no remains of mammals or birds in them, but there are traces of reptiles. Close by the side of the trail, you can see a line of tracks crossing the face of a sandstone boulder. They were made by a small four-footed creature, almost certainly a lizard-like reptile, running across a beach. Other rocks at the same level elsewhere, contain impressions of fern leaves and the wings of insects.

Overleaf *The Grand Canyon of the Colorado River*