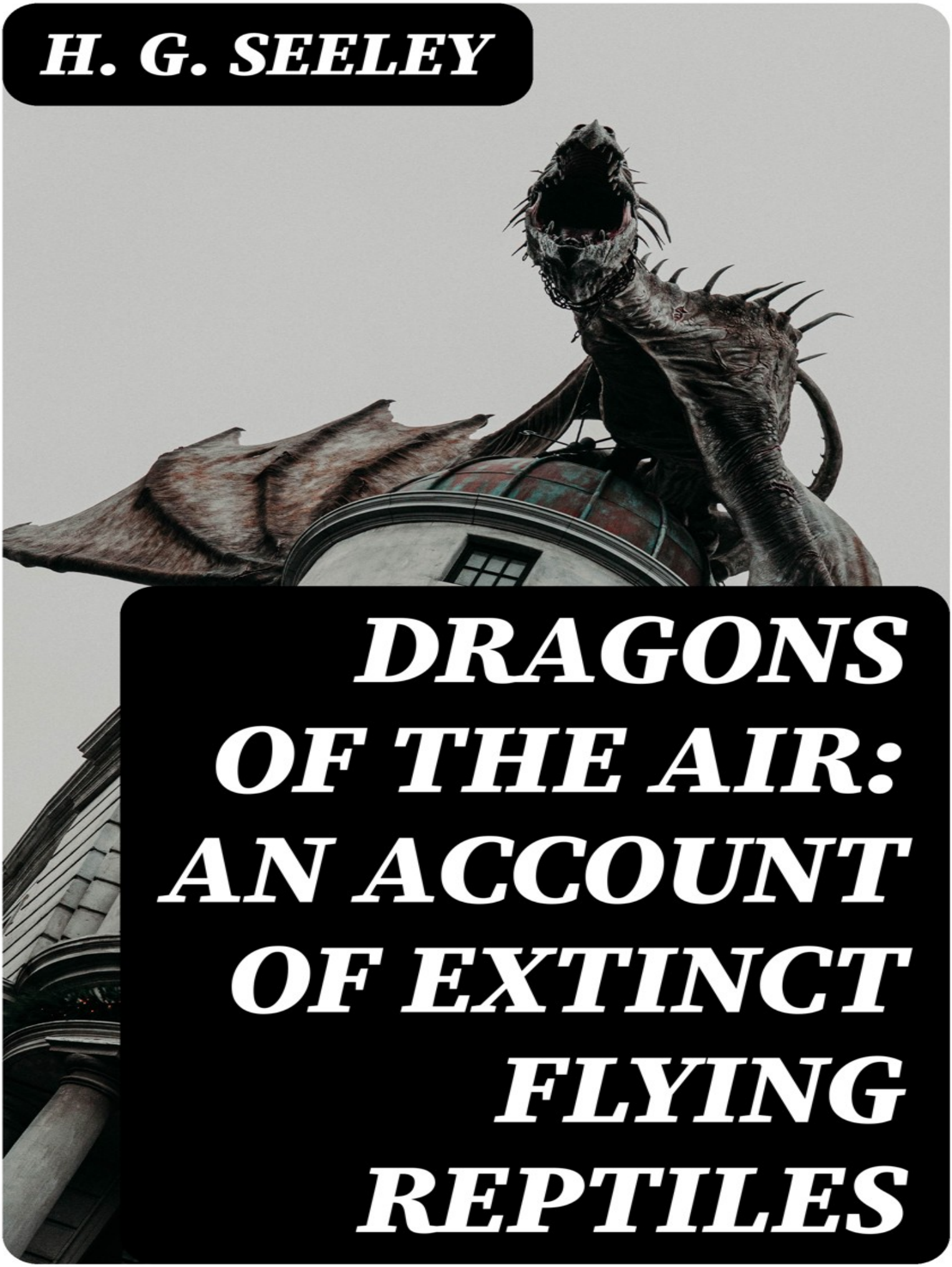
H. G. SEELEY



# DRAGONS OF THE AIR: AN ACCOUNT OF EXTINCT FLYING REPTILES

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# PREFACE

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I was a student of law at a time when Sir Richard Owen was lecturing on Extinct Fossil Reptiles. The skill of the great master, who built bones together as a child builds with a box of bricks, taught me that the laws which determine the forms of animals were less understood at that time than the laws which govern the relations of men in their country. The laws of Nature promised a better return of new knowledge for reasonable study. A lecture on Flying Reptiles determined me to attempt to fathom the mysteries which gave new types of life to the Earth and afterwards took them away.

Thus I became the very humble servant of the Dragons of the Air. Knowing but little about them I went to Cambridge, and for ten years worked with the Professor of Geology, the late Rev. Adam Sedgwick, LL.D., F.R.S., in gathering their bones from the so-called Cambridge Coprolite bed, the Cambridge Greensand. The bones came in thousands, battered and broken, but instructive as better materials might not have been. My rooms became filled with remains of existing birds, lizards, and mammals, which threw light on the astonishing collection of old bones which I assisted in bringing together for the University.

In time I had something to say about Flying Animals which was new. The story was told in the theatre of the Royal Institution, in a series of lectures. Some of them were repeated in several English towns. There was still much to learn of foreign forms of flying animals; but at last, with the aid of the Government grant administered by the Royal Society, and the chiefs of the great Continental museums, I saw all the specimens in Europe.

So I have again written out my lectures, with the aid of the latest discoveries, and the story of animal structure has lost nothing in interest as a twice-told tale. It still presents in epitome the story of life on the Earth. He who understands whence the Flying Reptiles came, how they endured, and disappeared from the Earth, has solved some of the greatest mysteries of life. I have only contributed something towards solving the problems.

In telling my story, chiefly of facts in Nature, an attempt is made to show how a naturalist does his work, in the hope that perhaps a few readers will find happiness in following the workings of the laws of life. Such an illumination has proved to many worth seeking, a solid return for labour, which is not to be marketed on the Exchange, but may be taken freely without exhausting the treasury of Nature's truths. Such outlines of knowledge as here are offered to a larger public, may also, I believe, be acceptable to students of science and scientific men.

The drawings given in illustration of the text have been made for me by Miss E. B. Seeley.

H. G. S.

KENSINGTON, *May, 1901*

These figures are greatly reduced in size, and when two or more bones are shown in the same figure all are brought to the same size to facilitate the comparison.

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# DRAGONS OF THE AIR

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## CHAPTER I

# FLYING REPTILES

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The history of life on the earth during the epochs of geological time unfolds no more wonderful discovery among types of animals which have become extinct than the family of fossils known as flying reptiles. Its coming into existence, its structure, and passing away from the living world are among the great mysteries of Nature.

The animals are astonishing in their plan of construction. In aspect they are unlike birds and beasts which, in this age, hover over land and sea. They gather into themselves in the body of a single individual, structures which, at the present day, are among the most distinctive characters of certain mammals, birds, and reptiles.

The name "flying reptile" expresses this anomaly. Its invention is due to the genius of the great French naturalist Cuvier, who was the first to realise that this extinct animal, entombed in slabs of stone, is one of the wonders of the world.

The word "reptile" has impressed the imagination with unpleasant sound, even when the habits of the animals it indicates are unknown. It is familiarly associated with life which is reputed venomous, and is creeping and cold. Its common type, the serpent, in many parts of the world takes a yearly toll of victims from man and beast, and has become the representative of silent, active strength, dreaded craft, and danger.

Science uses the word "reptile" in a more exact way, to define the assemblage of cold-blooded animals which in familiar description are separately named serpents, lizards, turtles, hatteria, and crocodiles.

Turtles and the rest of them survive from great geological antiquity. They present from age to age diversity of aspect and habit, and in unexpected differences of outward proportion of the body show how the laws of life have preserved each animal type. For the vital organs which constitute each animal a reptile, and the distinctive bony structures with which they are associated, remain unaffected, or but little modified, by the animal's external change in appearance.

The creeping reptile is commonly imagined as the antithesis of the bird. For the bird overcomes the forces that hold even man to the earth, and enjoys exalted aerial conditions of life. Therefore the marvel is shared equally by learned and unlearned, that the power of flight should have been an endowment of animals sprung from the breed of serpents, or crocodiles, enabling them to move through the air as though they too were of a heaven-born race. The wonder would not be lessened if the animal were a degraded representative of a nobler type, or if it should be demonstrated that even beasts have advanced in the battle of life. The winged reptile, when compared with a bird, is not less astounding than the poetic conceptions in Milton's *Paradise Lost* of degradation which overtakes life that once was amongst the highest. And on the other hand, from the point of view of the teaching of Darwin in the theories of modern science, we are led to ask whether a flying reptile

may not be evidence of the physical exaltation which raises animals in the scale of organisation. The dominance upon the earth of flying reptiles during the great middle period of geological history will long engage the interest of those who can realise the complexity of its structure, or care to unravel the meaning of the procession of animal forms in successive geological ages which preceded the coming of man.

The outer vesture of an animal counts for little in estimating the value of ties which bind orders of animals together, which are included in the larger classes of life. The kindred relationship which makes the snake of the same class as the tortoise is determined by the soft vital organs—brain, heart, lungs—which are the essentials of an animal's existence and control its way of life. The wonder which science weaves into the meaning of the word "reptile," "bird," or "mammal," is partly in exhibiting minor changes of character in those organs and other soft parts, but far more in showing that while they endure unchanged, the hard parts of the skeleton are modified in many ways. For the bones of the reptile orders stretch their affinities in one direction towards the skeletons of salamanders and fishes; and extend them also at the same time in other directions, towards birds and mammals. This mystery we may hope to partly unravel.

## CHAPTER II

# HOW A REPTILE IS KNOWN

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# DEFINITION OF REPTILES BY THEIR VITAL ORGANS

The relations of reptiles to other animals may be stated so as to make evident the characters and affinities which bind them together. Early in the nineteenth century naturalists included with the Reptilia the tribe of salamanders and frogs which are named Amphibia. The two groups have been separated from each other because the young of Amphibia pass through a tadpole stage of development. They then breathe by gills, like fishes, taking oxygen from the air which is suspended in water, before lungs are acquired which afterwards enable the animals to take oxygen directly from the air. The amphibian sometimes sheds the gills, and leaves the water to live on land. Sometimes gills and lungs are retained through life in the same individual. This amphibian condition of lung and gill being present at the same time is paralleled by a few fishes which still exist, like the Australian *Ceratodus*, the lung-fish, an ancient type of fish which belongs to early days in geological time.

This metamorphosis has been held to separate the amphibian type from the reptile because no existing reptile develops gills or undergoes a metamorphosis. Yet the character may not be more important as a ground for

classification than the community of gills and lungs in the fish and amphibian is ground for putting them together in one natural group. For although no gills are found in reptiles, birds, or mammals, the embryo of each in an early stage of development appears to possess gill-arches, and gill-clefts between them, through which gills might have been developed, even in the higher vertebrates, if the conditions of life had been favourable to such modification of structure. In their bones Reptiles and Amphibia have much in common. Nearly all true reptiles lay eggs, which are defined like those of birds by comparatively large size, and are contained in shells. This condition is not usual in amphibians or fishes. When hatched the young reptile is completely formed, the image of its parent, and has no need to grow a covering to its skin like some birds, or shed its tail like some tadpoles. The reptile is like the bird in freedom from important changes of form after the egg is hatched; and the only structure shed by both is the little horn upon the nose, with which the embryo breaks the shell and emerges a reptile or a bird, growing to maturity with small subsequent variations in the proportions of the body.

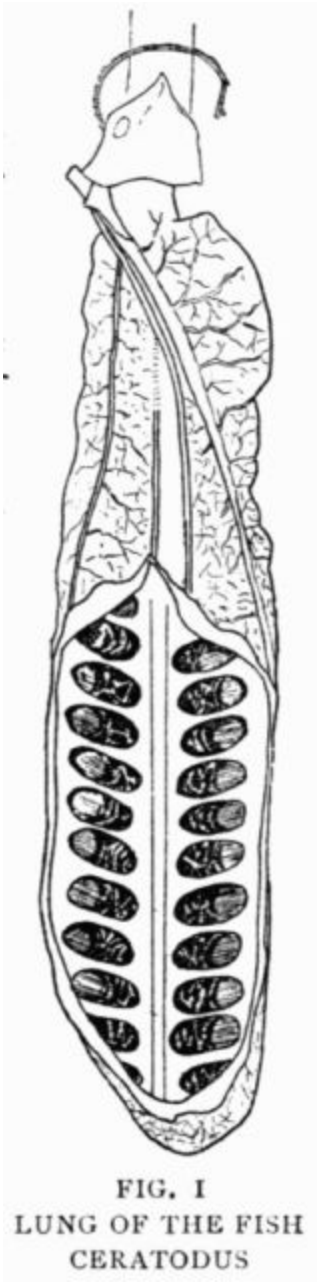

FIG. I
LUNG OF THE FISH
CERATODUS

FIG. 1 LUNG OF THE FISH CERATODUS

Partly laid open to show its chambered structure
(After Günther)

# THE REPTILE SKIN

Between one class of animals and another the differences in the condition of the skin are more or less

distinctive. In a few amphibians there are some bones in the skin on the under side of the body, though the skin is usually naked, and in frogs is said to transmit air to the blood, so as to exercise a respiratory function of a minor kind. This naked condition, so unlike the armoured skin of the true Reptilia, appears to have been paralleled by a number of extinct groups of fossils of the Secondary rocks, such as Ichthyosaurs and Plesiosaurs, which were aquatic, and probably also by some Dinosauria, which were terrestrial.

Living reptiles are usually defended with some kind of protection to the skin. Among snakes and lizards the skin has commonly a covering of overlapping scales, usually of horny or bony texture. The tortoise and turtle tribe shut up the animal in a true box of bone, which is cased with an armour of horny plates. Crocodiles have a thick skin embedding a less continuous coat of mail. Thus the skin of a reptile does not at first suggest anything which might become an organ of flight; and its dermal appendages, or scales, may seem further removed from the feathers which ensure flying powers to the bird than from the naked skin of a frog.

## THE REPTILE BRAIN

Although the mode of development of the young and the covering of the skin are conspicuous among important characters by which animals are classified, the brain is an organ of some importance, although of greater weight in the higher Vertebrata than in its lower groups. Reptiles have links in the mode of arrangement of the parts of their brains

with fishes and amphibians. The regions of that organ are commonly arranged in pairs of nervous masses, known as (1) the olfactory lobes, (2) the cerebrum, behind which is the minute pineal body, followed by (3) the pair of optic lobes, and hindermost of all (4) the single mass termed the cerebellum. These parts of the brain are extended in longitudinal order, one behind the other in all three groups. The olfactory lobes of the brain in Fishes may be as large as the cerebrum; but among Reptiles and Amphibians they are relatively smaller, and they assume more of the condition found in mammals like the Hare or Mole, being altogether subordinate in size. And the cerebral masses begin to be wider and higher than the other parts of the brain, though they do not extend forward above the olfactory lobes, as is often seen in Mammals. In Crocodiles the cerebral hemispheres have a tendency to a broad circular form. Among Chelonian reptiles that region of the brain is more remarkable for height. Lizards and Ophidians both have this part of the brain somewhat pear-shaped, pointed in front, and elongated. The amphibian brain only differs from the lizard type in degree; and differences between lizards' and amphibian brains are less noticeable than between the other orders of reptiles. The reptilian brain is easily distinguished from that of all other animals by the position and proportions of its regions (see Fig. 19, p. 53).

Birds have the parts of the brain formed and arranged in a way that is equally distinctive. The cerebral lobes are relatively large and convex, and deserve the descriptive name "hemispheres." They are always smooth, as among the lower Mammals, and extend backward so as to abut

against the hind brain, termed the cerebellum. This junction is brought about in a peculiar way. The cerebral hemispheres in a bird do not extend backward to override the optic lobes, and hide them, as occurs among adult mammals, but they extend back between the optic lobes, so as to force them apart and push them aside, downward and backward, till they extend laterally beyond the junction of the cerebrum with the cerebellum. The brain of a Bird is never reptilian; but in the young Mammal the brain has a very reptilian aspect, because both have their parts primarily arranged in a line. Therefore the brain appears to determine the boundary between bird and reptile exactly.

## REPTILIAN BREATHING ORGANS

The breathing organs of Birds and Reptiles which are associated with these different types of brain are not quite the same. The Frog has a cellular lung which, in the details of the minute sacs which branch and cluster at the terminations of the tubes, is not unlike the condition in a Mammal. In a mammal respiration is aided by the bellows-like action of the muscles connected with the ribs, which encase the cavity where the lungs are placed, and this structure is absent in the Frog and its allies. The Frog, on the other hand, has to swallow air in much the same way as man swallows water. The air is similarly grasped by the muscles, and conveyed by them downward to the lungs. Therefore a Frog keeps its mouth shut, and the animal dies from want of air if its mouth is open for a few minutes.

Crocodiles commonly lie in the sun with their mouths widely open. The lungs in both Crocodiles and Turtles are

moderately dense, traversed by great bronchial tubes, but do not differ essentially in plan from those of a Frog, though the great branches of the bronchial tubes are stronger, and the air chambers into which the lung is divided are somewhat smaller. The New Zealand Hatteria has the lungs of this cellular type, though rather resembling the amphibian than the Crocodile. The lungs during life in all these animals attain considerable size, the maximum dimensions being found in the terrestrial tortoises, which owe much of their elevated bulk to the dimensions of the air cells which form the lungs.

The lungs of Serpents and Lizards are formed on a different plan. In both those groups of reptiles the dense cellular tissue is limited to the part of the lung which is nearest to the throat. This network of blood vessels and air cells extends about the principal bronchial tube much as in other animals, but as it extends backward the blood vessels become few until the *tubular* lung appears in its hinder part, as it extends down the body, almost as simple in structure as the air bladder of a fish. Among Serpents only one of these tubular lungs is commonly present, and the structure has a less efficient appearance as a breathing organ than the single lung of the fish *Ceratodus* (Fig. 1). The Chameleons are a group of lizards which differ in many ways from most of their nearest kindred, and the lungs, while conforming in general plan to the lizard type in being dense at the throat, and a tubular bladder in the body, give off on both sides a number of short lateral branches like the fingers of a glove (Fig. 18, p. 51).

Thus the breathing organs of reptiles present two or three distinct types which have caused Serpents and Lizards to be associated in one group by most naturalists who have studied their anatomy; while Crocodiles and Chelonians represent a type of lung which is quite different, and in those groups has much in common. These characters of the breathing organs contribute to separate the cold-blooded armoured reptiles from the warm-blooded birds clothed with feathers, as well as from the warm-blooded mammals which suckle their young; for both these higher groups have denser and more elastic spongy lung tissue.

It will be seen hereafter that many birds in the most active development of their breathing organs substantially revert to the condition of the Serpent or Chameleon in a somewhat modified way. Because, instead of having one great bronchial tube expanded to form a vast reservoir of air which can be discharged from the lung in which the reptile has accumulated it, the bird has the lateral branches of the bronchial tubes prolonged so as to pierce the walls of the lung, when its covering membrane expands to form many air cells, which fill much of the cavity of the bird's body (see Fig. 16). Thus the bird appears to combine the characters of such a lung as that of a Crocodile, with a condition which has some analogy with the lung of a Chameleon. It is this link of structure of the breathing organs between reptiles and birds that constitutes one of the chief interests of flying reptiles, for they prove to have possessed air cells prolonged from the lungs, which extended into the bones.

## CHAPTER III

# A REPTILE IS KNOWN BY ITS BONES

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Such are a few illustrations of ways in which reptiles resemble other animals, and differ from them, in the organs by means of which the classification of animals is made. But such an idea is incomplete without noticing that the bony framework of the body associated with such vital organs also shows in its chief parts that reptiles are easily recognised by their bones. I will therefore briefly state how reptiles are defined in some regions of the skeleton, for in tracing the history of reptile life the bones are the principal remains of animals preserved in the rocks; and the soft organs which have perished can only be inferred to have been present from the persistence of durable characteristic parts of the skeleton, which are associated with those soft organs in animals which exist at the present day, and are unknown in other animals in which the skeleton is different.

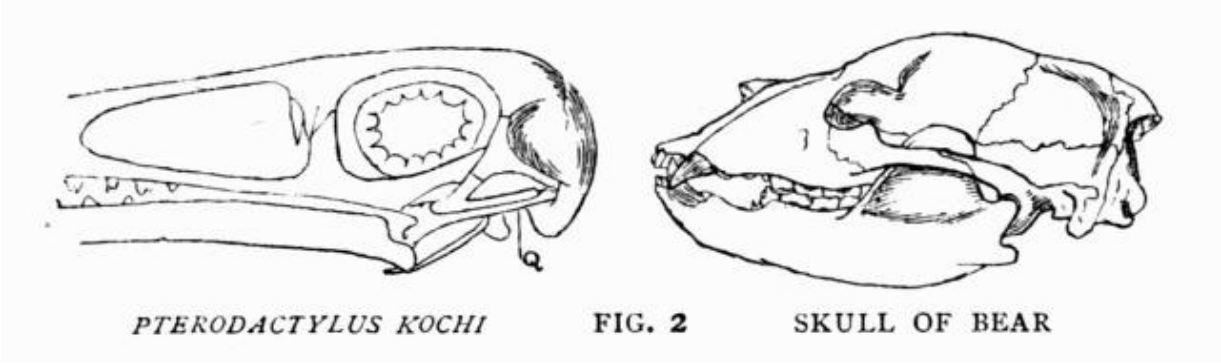
## THE HANG OF THE LOWER JAW

The manner in which the lower jaw is connected with the skull yields one of the most easily recognised differences between the great groups of vertebrate animals.

*In Mammals.*—In every mammal—such as the Dog or Sheep—the lower jaw, which is formed of one bone on each side, joins directly on to the head of the animal, and moves upon a bone of the skull which is named the temporal bone.

This character is sufficient to prove, by the law of association of soft and hard parts of the body, that such an animal had warm blood and suckled its young.

FIG. 2




*PTERODACTYLUS KOCHI* FIG. 2 SKULL OF BEAR

Comparison to show the articulation with the lower jaw in a mammal and *Pterodactylus Kochi*.
The quadrate bone is lettered Q in this Pterodactyle, and comes between the skull and
the lower jaw like the quadrate bone in a bird and in lizards.

*In Birds.*—In birds a great difference is found in this region of the head. The temporal bone, which it will be more convenient to name the squamosal bone, from its squamous or scale-like form, is still a part of the brain case, and assists in covering the brain itself, exactly as among mammals. But the lower jaw is now made up of five or six bones. And between the hindermost and the squamosal there is an intervening bar of bone, unknown among mammalia, which moves upon the skull by a joint, just as the lower jaw moves upon it. This movable bone unites with parts of the palate and the face, and is known as the quadrate bone. Its presence proves that the animal possessing it laid eggs, and if the face bones join its outer border just above the lower jaw, it proves that the animal possessed hot blood.

*In Reptiles.*—All reptiles are also regarded as possessing the quadrate bone. But the squamosal bone with which it always unites is in less close union with the brain case, and never covers the brain itself. Serpents show an extreme divergence in this condition from birds, for the squamosal bone appears to be a loose external plate of bone which rests upon the compact brain case and gives attachment to the quadrate bone which is as free as in a bird. Among Lizards the quadrate bone is usually almost as free. In the other division of existing Reptilia, including Crocodiles, the New Zealand lizard-like reptile Hatteria, called Tuatera, and Turtles, the squamosal and quadrate bones are firmly united with the bones of the brain case, face, and palate, so that the quadrate bone has no movement; and the same condition appears in amphibians, such as Toads and Frogs. With these conditions of the quadrate bone are associated cold blood, terrestrial life, and young developed from eggs.

*In Fishes.*—Bony fishes, and all others in which separate bones build up the skull, differ from Reptiles and Birds much as those animals differ from Mammals. The union of the lower jaw with the skull becomes complicated by the presence of additional bones. The quadrate bone still forms a pulley articulation upon which the lower jaw works, but between it and the squamosal bone is the characteristic bone of the fish known as the hyomandibular, commonly connected with opercular bones and metapterygoid which intervene, and help to unite the quadrate with the brain case. In the Cartilaginous fishes there is only one bone connecting the jaws with the skull on each side. This appears to prove that just as the structure of the arch of

bones suspending the jaw may be complicated by the mysterious process called segmentation, which separates a bone into portions, so simplification and variation may result because the primitive divisions of the material cease to be made which exists before bones are formed.

The principal regions of the skull and skeleton all vary in the chief groups of animals with backbones; so that the Reptile may be recognised among fossils, even in extinct groups of animals and occasionally restored from a fragment, to the aspect which characterised it while it lived.

## CHAPTER IV

# ANIMALS WHICH FLY

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The nature of a reptile is now sufficiently intelligible for something to be said concerning flight, and structures by means of which some animals lift themselves in the air. It is not without interest to remember that, from the earliest periods in human records, representations have been made of animals which were furnished with wings, yet walked upon four feet, and in their typical aspect have the head shaped like that of a bird. They are commonly named Dragons.

## FLYING DRAGONS

FIG. 3 From *The Battle between Bel and the Dragon*

FIG. 3
From *The Battle between Bel and the Dragon*

The effigy of the dragon survives to the present day in the figure over which St. George triumphs, on the reverse of the British sovereign. In the luxuriant imaginations of ancient Eastern peoples, dating back to prehistoric ages, perhaps 5000 B.C., the dragons present an astonishing constancy of form. In after-times they underwent a curious evolution, as the conception of Babylon and Egypt is traced

through Assyria to Greece. The Wings, which had been associated at first with the fore limb of the typical dragon, become characteristic of the Lion, and of the poet's winged Horse, and finally of the Human figure itself, carved on the great columns of the Greek temples of Ephesus. These flying animals are historically descendants of the same common stock with the dragons of China and Japan, which still preserve the aspect of reptiles. Their interest is chiefly in evidence of a latent spirit of evolution in days too remote for its meaning to be now understood, which has carried the winged forms higher and ever higher in grade of organisation, till their wings ceased to be associated with feelings of terror. The Hebrew cherubim are regarded by H. E. Ryle, Bishop of Exeter, as probably Dragons, and the figure of the conventional angel is the human form of the Dragon.

FIG. 4. FIGURE FROM THE TEMPLE OF EPHESUS

FIG. 4. FIGURE FROM THE TEMPLE OF EPHESUS

# ORGANS OF FLIGHT

Turning from this reference to the realm of mythology to existing nature, the power of flight is popularly associated with all the chief types of vertebrate animals—fishes, frogs, lizards, birds, and mammals. Many of the animals ill deserve

the name of flyers, and most are exceptions to different conditions of existence which control their kindred, but it is convenient to examine for a little the nature of the structures by which this movement in the air, which is not always flight, is made possible. Certain fishes, like the lung-fish Ceratodus, of Queensland, and the mud-fish Lepidosiren, are capable of leaving the water and living on land, and for a time breathe air. But neither these fishes nor Periophthalmus, which runs with rapid movement of its fins and carries the body more or less out of water, or the climbing perch, Anabas, carried out of water over the country by Indian jugglers, ever put on the slightest approach to wings.

## FLYING FISHES

FIG. 5. THE FLYING FISH EXOCŒTUS

With the fins extended moving through the air

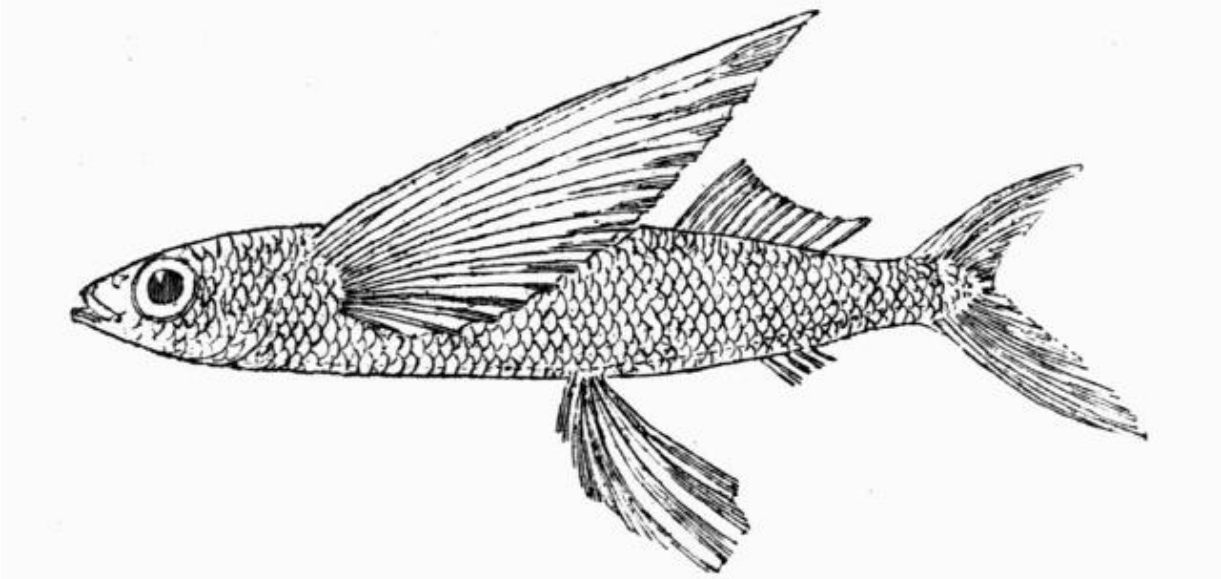

FIG. 5. THE FLYING FISH EXOCŒTUS
With the fins extended moving through the air

The flight of fishes is a kind of parachute support not unlike that by which a folded paper is made to travel in the air. It is chiefly seen in the numerous species of a genus Exocœtus, allied to the gar-pike (Belone), which is common in tropical seas, and usually from a foot to eighteen inches long. They emerge from the water, and for a time support themselves in the air by means of the greatly developed breast fins, which sometimes extend backward to the tail fin. Although these fins appear to correspond to the fore limbs of other animals, they may not be moved at the will of the fish like the wing of a bird. When the flying fishes are seen in shoals in the vicinity of ships, those fins remain extended, so that the fish is said sometimes to travel 200 yards at a speed of fifteen miles an hour, rising twenty feet or more above the surface of the sea, travelling in a straight line, though sometimes influenced by the wind. Here the organ, which is at once a fin and a wing, consists of a number of thin long rods, or rays, which are connected by

membrane, and vary in length to form an outline not unlike the wing of a bird which tapers to a point. The interest of these animals is chiefly in the fact that flight is separated from the condition of having lungs with which it is associated in birds, for although the flying fish has an air bladder, there is no duct to connect it with the throat.

## FLYING FROGS

FIG. 6. THE FLYING FROG (RHACOPHORUS)

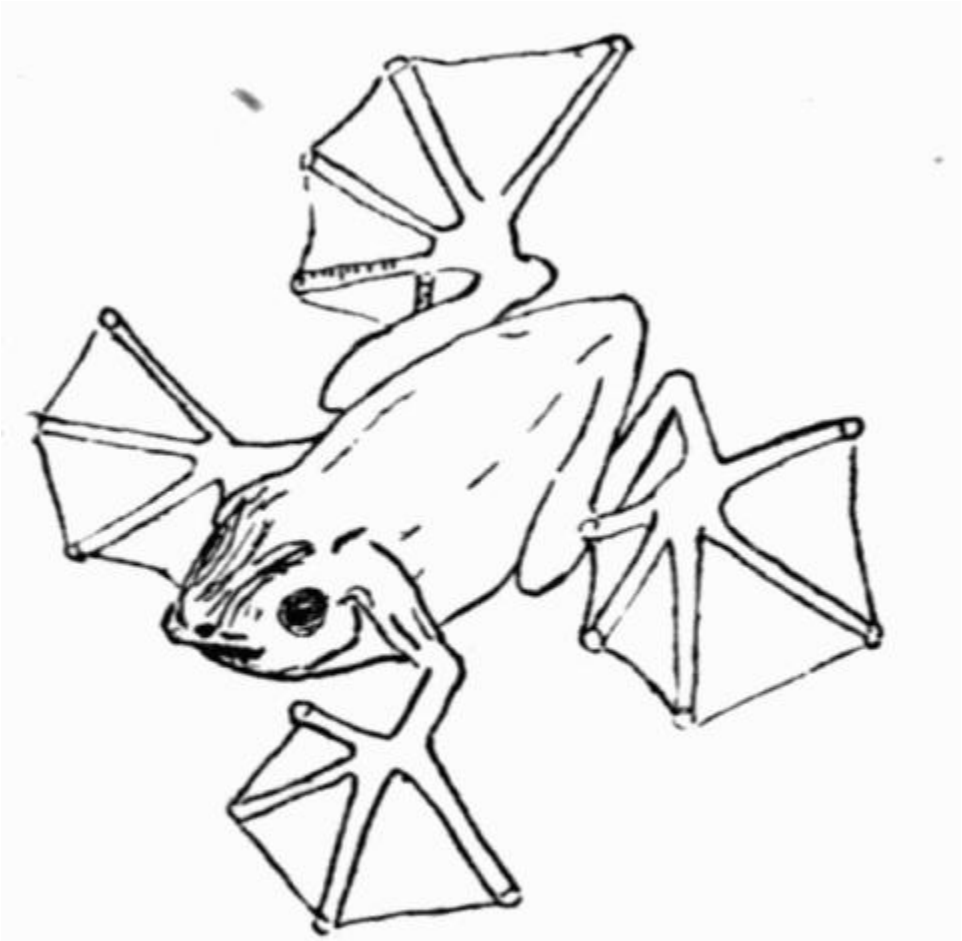

FIG. 6. THE FLYING FROG (RHACOPHORUS)