LIFE NATURE LIBRARY

THE REPTILES

LIFE NATURE LIBRARY

THE REPTILES

by Archie Carr
and The Editors of LIFE

TIME-LIFE INTERNATIONAL (Nederland) N.V.

About the Author

Archie Carr, though born in Mobile, Alabama, has long been as much a part of Florida as the reptiles there he knows and loves so well. He went to college at the University of Florida, received his M.S. and his Ph.D. there and has taught in the biology department of that institution since 1937. Today he is a graduate research professor at the university, but is known far beyond the boundaries of Florida as probably the greatest authority on sea turtles in the world. Fascinated by turtles and snakes from the time he was a boy, Dr. Carr's studies have taken him to distant places as a biologist and adviser to corporations, commissions and governments. He is particularly identified with the Caribbean Conservation Corporation, an organization dedicated to saving the green turtle from extinction, but he has also worked extensively on other continents, notably Africa. A prolific writer as well as scientist, he is the author of seven books, numerous scientific papers and several short stories, one of which won the O. Henry Award in 1956. That same year he also won the Daniel Giraud Elliott medal for preeminence in zoology and the John Burroughs medal for nature writing.

ON THE COVER: In a head-on view, a bamboo viper from Formosa gleams like polished jade. The deep pits between the red eyes are heat-sensing organs that help this poisonous snake to locate and strike its warm-blooded prey.

Contents

TIME/LIFE BOOKS

Editor: MAITLAND A. EDEY

Text Director: JERRY KORN *Art Director:* SHELDON COTLER

Chief of Research: BEATRICE T. DOBIE

•

EDITORIAL STAFF FOR "THE REPTILES"

Editor, LIFE Nature Library: MAITLAND A. EDEY

Assistant to the Editor: JOHN PURCELL

Text Editor: PERCY KNAUTH

Chief Researcher: MARTHA TURNER

The text for the chapters of this book was written by Archie Carr, the picture essays by the editorial staff. The following individuals and departments of Time Inc. were helpful in producing the book. LIFE staff photographers Larry Burrows, Alfred Eisenstaedt, Eliot Elisofon, Fritz Goro and Nina Leen, the Chief of the LIFE Picture Library, Doris O'Neil; the Chief of the TIME-LIFE News Service, Richard M. Clurman; and the Chief of the Time Inc. Bureau of Editorial Reference, Peter Draz. This international edition adapted by Paul Cooke Wilkins.

Preface

REPTILES have been in existence for some 300 million years, but they came into their own just a few decades ago—at least in the mind of the average American. Part of this latter-day awakening of interest and tolerance may stem from the flood of recent herpetological research, but much more originates from public awareness, at long last, that most reptiles, serpents included, are of interest and value, and not all are terrifying monsters fit only to be slaughtered at every opportunity

Probably the long-extinct dinosaurs have contributed their share to this improved state of affairs. At least they are familiar to all of us, thanks to the restorations of the palaeontologists. We see their likenesses frequently—in cartoons and advertisements, as small boys' toys, or in the "bones" at the museum—and usually they are portrayed as symbols of power and life in the raw during bygone ages. But the baby turtle, the "chameleon" bought at the circus and the pet snake, which find their way into so many private houses, are the stuff from which enthusiasm springs among the youth of today. They ensure a large and appreciative audience for this book about a remarkable group of animals by a gifted and eloquent professor of biology.

If only we could see for ourselves some of the grotesque monsters of yesteryear! In a sense we have come too late. We are witnessing the closing scene of the last act of a natural drama that has known no equal. Arising from feeble ancestors in a new and hostile environment, the reptiles branched out in all directions and for a long time were dominant. Those that survive are meagre remnants of the long-dead hordes, and at least some—the turtles, crocodiles and tuatara—eminently qualify for that hackneyed but beautifully descriptive appellation of living fossils.

There may be a lesson for us in the rise and fall of the great reptiles. We human beings are riding high today, and many of us give little thought to the future despite the threat of atomic war, our fantastically burgeoning population and our profligate wastage of natural resources. Let one or more of these dangers pass beyond control, and mankind may find itself vastly reduced in numbers and struggling for survival as so many of the reptiles are today. There is much food for thought in Dr. Carr's concluding chapter.

At least some of the reptiles are making a reappearance, or they were until we began polluting our streams, poisoning our countryside with insect sprays and bulldozing so many of their habitats out of existence. These are the snakes and the lizards, creatures that, in their own ways, are fully as fascinating as *Tyrannosaurus*, *Brontosaurus* and *Pteranodon* of the Age of Reptiles. So in fact are all the rest of the surviving groups, particularly the turtles, which are Dr. Carr's first love and passionate interest. This is a wonderful book. You will enjoy reading it and will learn a lot as you do.

ROGER CONANT
Director and Curator of Reptiles, Philadelphia Zoological Garden
Research Associate, American Museum of Natural History
and The Academy of Natural Sciences of Philadelphia

SUSPICIONS ABOUT SNAKES, almost universal among humans, are betrayed by a girl in a children's zoo. Her fears are unwarranted. The snake, a California rosy boa, is harmless; it will not even try to bite.

1

The "Cold-Blooded" Fraternity

THE reactions of the little girl on the opposite page epitomize the feelings of people generally about reptiles. Most people have a vague feeling that no reptiles except turtles are to be trusted, and so make no effort to find out anything about them or even to learn what they are. It would scarcely be necessary in writing a book about birds, say, to make sure at the outset that the reader knew what birds were, but in the case of reptiles this is sadly true. Therefore one should start with a definition that excludes frogs, toads, platypuses, mudskippers, armadillos, and a good many other odd animals which are constantly being mistakenly included with reptiles.

A true reptile, to begin with, is a vertebrate animal. It has scales, breathes air (not water), characteristically lays shell eggs and depends on outside sources for its body heat. There are in the world only five main groups of animals that fit this definition. They are the turtles, the lizards, the snakes, the crocodilians, and a strange, little-seen creature called the tuatara, which looks like a lizard but is not. In these latest days of geologic history, there are about 6,000 species of reptiles scattered over the earth. Though they are most diverse and numerous in warm regions, they range far northwards too, turning up in

the gardens of rural Swedes, Siberians and Canadians. They even occur on the dusty deserts of the world.

It so happens that I live in Florida, which is one of the good reptile regions. I have a farm with woods around it and a marshy pond in front. The place offers a fine sample of the main groups of reptiles. The farm is no Cretaceous swamp, but through the years we have caught, seen, stepped on or had the house invaded by a great many different kinds of reptiles, representing all the main groups except the tuatara.

To begin with, the farm is extraordinarily blessed with turtles, and a stroll around it gives a good, broad impression of turtle architecture and customs. The turtles there are both aquatic and terrestrial. They spread in size from the four-inch stinkpots to snappers that weigh 30 pounds or more and in disposition from the long-necked, short-tempered, carnivorous soft-shells that lurk on the pond bottom snorkelling air through tubular nostrils to the various placid, dome-shelled water turtles, called cooters in Florida, which bask on logs, forage for edible trash on the bottom or cruise about nibbling at fallen flower petals floating on the water. Industrious gopher turtles follow their small trails out from vaulted burrows and graze among the browsing cows. Once in a long while a box turtle comes meditating through the garden and retires into its shell until we go away. Turtles are the most conservative of living reptiles, and the box turtle seems to me the spiritual essence of turtle mildness and conservatism.

In calling turtles conservative I have mainly in mind their devotion to an ancestral architecture devised a very long time ago—certainly not the architecture itself, which is about the most bizarre modification of vertebrate structure ever made. For the speciality of turtles is armour, a shell made up of a top part (the carapace) and a lower part (the plastron). The two parts are generally joined at each side by a bony bridge. Top and bottom, the shell has two layers, an outer one made up of broad, horny scales joined by stout seams and an inner, usually much thicker layer of tightly jointed bones. Because the seams of these two mosaics do not coincide, the whole structure forms an extremely strong casing within which much, and in some cases all, of the turtle can be safely stowed away.

THE origin of this shell has not been convincingly revealed by palaeontologists, and so it is not possible to say just where in the reptile record the turtle line begins. A little reptile called Eunotosaurus that lived some 250 million years ago in the Permian age is often pointed to as a probable turtle ancestor. It had ribs which were broadened in a way that suggests a rudimentary shell. But whatever the beginnings of turtles may have been, the shell is now the mark of the creature. In spite of the millions of years of evolution that have seen turtles established nearly everywhere on the earth except in the air, the shell, in some readily recognizable form, has been retained.

The advantage the shell brought must have been strong, because it is not an easy thing to live with. Embryologically, it is a sort of nightmare. To live in it and keep their front legs working properly, turtles had to rearrange their shoulder girdle, bringing it back into an unprecedented position inside the rib case. This is not a thing that happened once back in the Permian and then was done for ever. Each time an embryo becomes a turtle it happens all over again, just as each baby plaice is first an upright fish with an eye on either side, and then later becomes flattened, with both eyes on the same side.

The shell has also dictated a change in the method of breathing. Because

THE ABUNDANCE OF REPTILES TODAY

Of the 16 orders of reptiles known from fossils, only four have managed to survive until modern times. The largest by far, the Squamata, combines both lizards and snakes, with a grand total of about 5,700 living species. By contrast, there are only 200 species of turtles and 23 species of crocodilians throughout the world, and the tuatara alone in New Zealand. The last two were not always so scarce. Fossils of at least 108 species of extinct crocodilians are known. And the rhynchocephalian order, to which the tuatara belongs, once numbered at least 23 species.

a turtle cannot expand its chest at all, it must suck in air by certain internal movements. By contracting a pair of muscles back at the flanks, the turtle can increase the volume of the space around the lungs, and the air rushes in. To expel air, it contracts another set of muscles under the viscera, pushing the internal organs forward to squeeze against the lungs. A number of other physiological adjustments make breathing a distinctive process in turtles and, incidentally, one about which a great deal remains to be learned.

Turtles range in weight from a few ounces to well over half a ton. The biggest turtles are aquatic, but there are big ones on land too. The famous Galápagos tortoises, and others on islands in the Indian Ocean, have reached weights of over 400 pounds. During the Pleistocene, there were even bigger ones in various parts of the world.

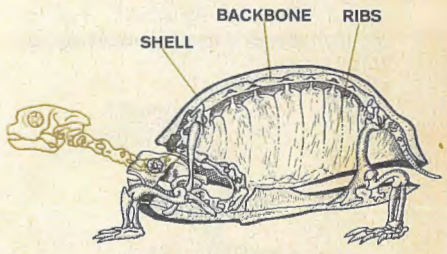
THERE is a popular notion that turtles live, as it were, for ever, but because little is known scientifically about their maximum life span it is not possible to evaluate this. Careful sifting of records from zoos, and of the generally shaky evidence afforded by turtles with dates carved into their shells, has led some herpetologists, as students of reptiles are known, to suggest a figure of a hundred years as a probable maximum. Few turtles living near man realize this potentiality. They get run over on the road, their marshes or ponds are drained, their streams are poisoned, or they are simply caught and eaten. Fortunately for their survival, their longevity does not mean they are slow to mature. In fact, turtles reach sexual maturity in a surprisingly short time. In the several species for which data are available, including some of the big sea turtles, breeding may begin at ages from three to eight years.

The most distinctive of living turtles is the giant leatherback sea turtle. Though it looks like a turtle, it has no proper turtle shell, but only a rubbery skin covering a mosaic of little, pebble-like bones which have nothing to do with the broad bones of the ordinary turtle carapace and are not connected to the skeleton at all. While the four other genera of sea turtles show some modification of the bony carapace, their shells are more like those of land and freshwater turtles. Another turtle group that stands apart is that of the soft-shelled, or pancake, turtles, found in Africa, Asia and North America. In these the horny shell is also replaced by a continuous skin, and the edge is thin, soft cartilage with no supporting marginal bones.

The motley array of the remaining kinds of turtles falls into two main groups, according to the way they draw in their necks. Most of them, the Cryptodira (hidden necks), retire with the neck bent into a vertically folding, S-shaped curve. They are found in Europe, Asia, Africa and the Americas. The other group, the side-necked turtles (Pleurodira), brings the neck in sideways and lays it along the body under the fore eaves of the shell. Side-necks are confined to tropics of the southern continents, Africa, South America and Australia. One of them is the famous matamata (*Chelys fimbriata*), the most grotesque-looking of all the turtles. The matamata, in fact, does not look like a turtle at all; it looks like a pile of leaves. In Colombia, where it is fairly common in swampy streams, and where a particular region contains a strain of extremely homely Indians, the women of this group are sometimes referred to as having *cara de matamata*, the face of a matamata. I presume that this is not said to their faces!

From the standpoint of abundance and diversity, the lizards and snakes are by far the most flourishing reptiles of today. Between them the two groups include about 600 genera and at least 5,700 species. They occur on every conti-

STRUCTURAL TROUBLES OF TURTLES



The internal rearrangements that a turtle has to put up with in order to live inside a hard shell are drastic. The creature's backbone has become fused to the shell. Its ribs are flattened and widened like fence palings to ensure maximum support. Its shoulder blades and hips are inside what would be the chest of a more conventional vertebrate. Its neck is long and flexible and can be retracted in an S-curve, pulling the head inside the shell for safety.

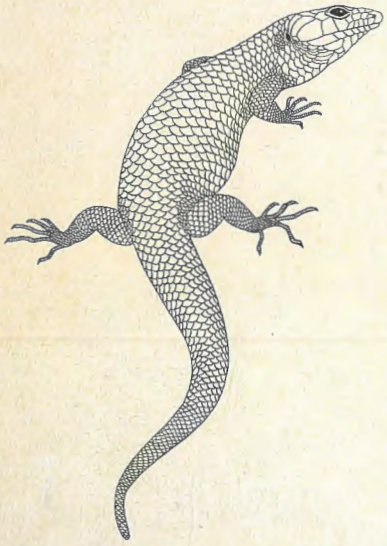
nent except Antarctica. Snakes are clearly derived from some ancient kind of lizard, and the two are put together in the order Squamata.

One of the features distinguishing the lizards and snakes from other reptiles is a drastic reduction of bones in the temporal region of the skull, which reaches its extreme among the snakes. Another is that the anal opening in lizards and snakes it transverse, instead of longitudinal as in crocodilians and turtles. Finally, both snakes and lizards have paired copulatory organs, and both have distinctive sets of sensory cells in their mouths, called Jacobson's organs.

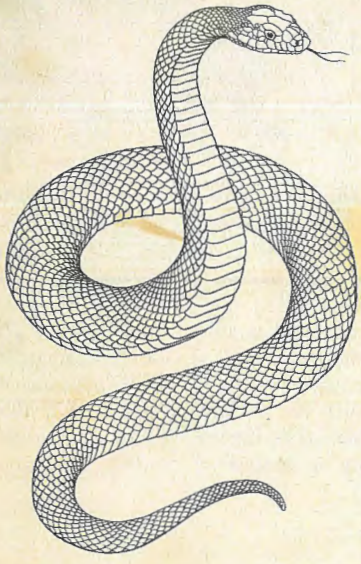
As to differences between snakes and lizards themselves, most lizards can close their eyes, but a snake's eyes remain permanently open behind a clear covering called the spectacle. The unblinking stare of snakes may account for some of the superstitious fears people have about them. Snakes also generally have a single row of widened scales under the belly, while the scales of lizards tend to be more nearly the same size above and below. Lizards typically have some sort of external ear; snakes have none. In most lizards the tail can be readily shed, evidently as an escape mechanism. In some, the broken-off section snaps and jumps about in an uncontrolled way. It is easy to imagine that this allows the rest of the lizard to slip quietly away from the scene while its attacker is preoccupied with the twitching tail. Later, a new tail generally grows again, sometimes lighter in colour, with a different scale pattern and shorter than the one that was left behind.

The most obvious difference between typical lizards and snakes, however, is the leglessness of the latter. Although there are lizards that have no legs and that superficially resemble snakes, it is still generally easy to draw the line between the two groups. At the same time, it is also helpful to keep in mind that snakes are really a specialized and quite successful sort of lizard.

HOW LIZARDS DIFFER FROM SNAKES



Although lizards and snakes belong to the same reptilian order, they have clearly visible differences. A typical lizard moves about on four limbs. It hears air-borne sounds through external ear openings, and sees with an eye which may be covered by two movable eyelids. The typical snake, on the other hand, moves by undulating its body and is aided by broad ventral scales which catch against the ground and keep it from slithering backwards. It can only hear through its skull bones, which transmit vibrations from the ground. A glassy transparent scale covers its unwinking eye.



Of the two groups of the Squamata, the lizards are of course the older. They have the conventional body plan of a typical land vertebrate: four legs, five toes to a foot, and the sprawling gait of the earliest reptiles. Most of the adaptations that have allowed them to spread and prosper are relatively unspectacular changes in the old four-legged look—exceptions being the various groups in which the legs have been lost completely. As vertebrates, lizards are a fairly representative group and it has been suggested that the lizard would be more suitable as a type with which to introduce biology students to vertebrate anatomy than the universally used frog. Perhaps it sounds cynical to say so, but I think the answer there is that the frog, being tailless, fits dissection pans more gracefully.

In spite of their fundamentally conventional body plan, modern lizards are a diverse lot. They range in length from two inches to 10 feet. They may look like dragons and they may look like worms, and they show a complex adaptive range through terrestrial, arboreal, subterranean and aquatic environments.

On my farm lizards are all over the place on warm days. The large family of the Iguanidae is there, represented by the slender anole that stalks insects on the screens, and by the scaly-backed fence lizards that bask on almost every log or stump. This is, as the name suggests, the group to which the big tropical arboreal and marine iguanas belong, and it includes a host of smaller forms. Its counterpart in the Old World is the family Agamidae, which has a curiously similar structural and ecological spread.

The classic lizards—classic because they are of the Old World and since early times have beguiled European naturalists—are the personable lacertas of

the family Lacertidae. My farm is, of course, devoid of lacertas, and this is a shame. Their place is partly taken by the athletic, silky six-lined racerunner, *Cnemidophorus*, a member of the related family Teiidae. The teiids are an alert and active group of lizards that occur mostly in South America but are also found foraging among chickens and babies in villages throughout the Caribbean. At the farm the racerunner streaks across the paths, and throughout the summer the hot, bare sand in all the open places is slashed with its tracks.

The most cosmopolitan lizard family is that of the skinks, the Scincidae—shiny-scaled lizards with protrusible tongues and a generally surreptitious air, which may account for their being occasionally known as scorpions. One of the farm skinks, the ground lizard, is a brown creature not much bigger than a wooden matchstick. The other is the big, burnished red-headed "scorpion", which confuses squirrel hunters with the noise it makes running up the trunks of trees.

A DAY of ploughing or harrowing is likely to turn up two kinds of lizards that have no legs. One is the so-called glass snake, which dashes headlong into the soil and makes one wonder why a British relative is known as the slow-worm. The other is the Florida worm lizard, a blind, pink, double-ended creature like a blunt lob worm. The worm-lizard family is called Amphisbaenidae, literally meaning "to walk on both ends", because among most of the creatures in it both ends look surprisingly alike. As these two burrowers show, snakes were not the only legless descendants of the ancestral lizard stocks. Through the world list of lizard families, legless members repeatedly turn up, a drastic adaptation that seems odd to a beast as dependent on his legs as man.

The giants among modern lizards are the monitors (family Varanidae), which are believed to be close to the ancestral line from which snakes came. In the East Indies, there is a monitor aptly if over-sensationally known as the Komodo "dragon" that reaches a length of over 10 feet, and there are African and Asian species that by far exceed the average size for modern lizards. Monitors are fierce predators which run down and kill quite large prey. They have long, flexible necks, protrusible tongues like snakes, and an intense way of looking at people that makes them feel uneasy.

There are no monitors on the farm, nor indeed are there any wild ones anywhere in the Western Hemisphere. There are no real chameleons out there either, or any Gila monsters. But the greatest deprivation we suffer is the lack of geckos. To residents of the tropics all over the world, the geckos—lizards of the family Gekkonidae—are a familiar institution. Geckos have many features that endear them to the open-minded. They live trustingly in people's houses. They have loose skins, vertical pupils, no eyelids and a voice—the only voice among lizards and one of the few really reliable voices in the whole class of reptiles. The name gecko is an effort at onomatopoeia, being suggestive of the sounds made by an Old World species known technically (and a bit redundantly) as *Gekko gekko*. A South African gecko, *Ptneopus garrulus*, gets its specific name from the habit of calling vociferously from the mouths of burrows that it makes on hillsides. Almost everybody who knows geckos is fond of them. Even people who mistakenly believe they are poisonous seem secretly pleased to have them around. The herpetologist Clifford Pope speaks of their magnetism and suggests that they may surpass baby turtles as potential pets. I agree, with but one reservation: a child is apt to be horrified when a gecko reacts to having its tail pulled by simply dropping off the tail into the child's hand.

A DISPOSABLE TAIL

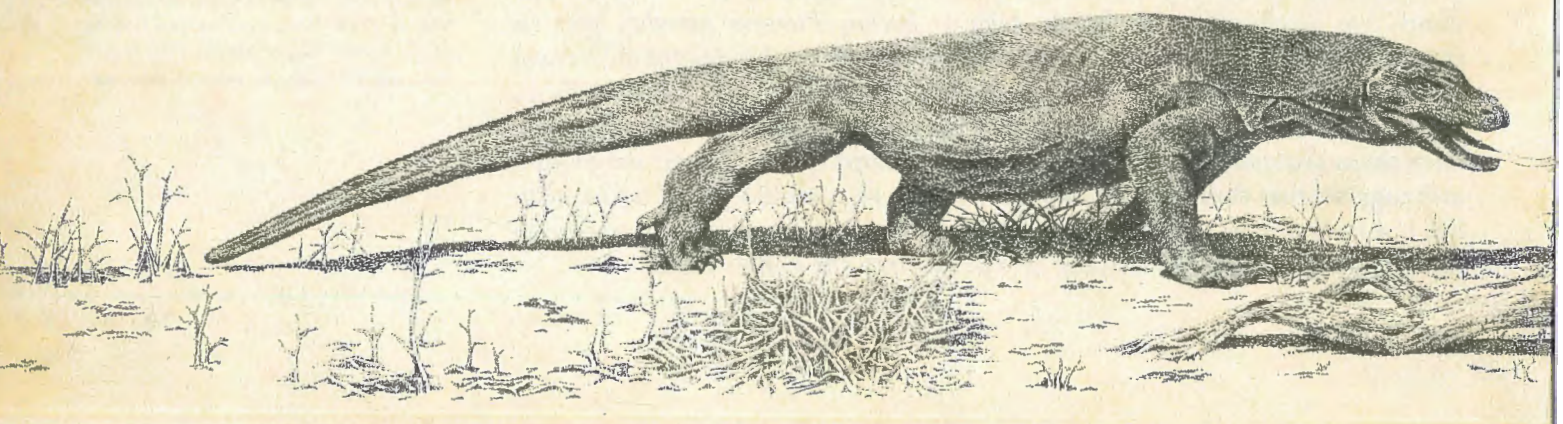
At the touch of a badger, a small lizard gives its hungry foe the slip by dropping its tail. This disconcerting defence is used by many lizards. The spot where the tail can break off is pre-set by a crack in a vertebra, and the muscles near by are also arranged so that they will separate neatly. As if this sudden splitting of one succulent morsel into two were not enough, the predator's momentary confusion is increased by the lively twisting and turning of the severed tail, while the little lizard darts off in safety to grow a new one.

We come now to the snakes, and it is interesting, in the light of their close relationship to, and derivation from, lizards, that some of the most primitive living snakes are burrowers whose skeletons retain traces of the old limb girdles from ancient lizard times. One family, the worm snakes (family Typhlopidae), is made up of tiny species with much reduced eyes and teeth, blunt heads, little scales and even the remnants of a pelvis. They have some features that have led some experts to suggest that they are not snakes at all, but are actually aberrant lizards.

Much better known, more conspicuous and far more numerous are the four principal snake families, the Boidae, the Colubridae, the Viperidae and the Elapidae. The first of these, and the most primitive, includes the New World boas and anacondas, and the pythons of the Old World tropics. They are constrictors: they kill their prey by wrapping themselves around it and squeezing. Although there are some small members of the group, the Boidae as a family are notorious for being the largest snakes in the world. There are well-authenticated records of anacondas more than 37 feet long, pythons of 33 feet, boa constrictors of 18 feet. Generally speaking, pythons and boas resemble each other closely, but the former lay eggs and the latter bear live young. There are also slight skeletal differences between them.

THE second major snake family, the Colubridae, is by far the most diversified. It contains about two-thirds of the world's snakes which, for want of a better name, go under the general heading of "typical" snakes. There are colubrids wherever snakes are found. As might be expected, they are the most numerous and most varied snakes on my Florida farm. Within a hundred yards of the house you can find snakes to show the main colubrid habits and habitats. Down at the pond edge, for instance, if you go to see why a frog is screaming, you will probably find that a water snake—a banded or green water snake—has hold of it, or perhaps a common garter snake. Or if it is a tiny, thin scream it may be that a ribbon snake is trying to swallow a gangling tree frog. The most ubiquitous snakes on the place are the black snake and the rat snake, or chicken snake. The two belong to different but related groups with world-wide distribution. The chicken snake is an *Elaphe*, a slow-moving, mainly arboreal constrictor, most readily found by joining any conclave of irate blue jays. The black snake belongs to the genus *Coluber*, which, with the whip snakes, includes some of the most agile and enterprising snakes in the world.

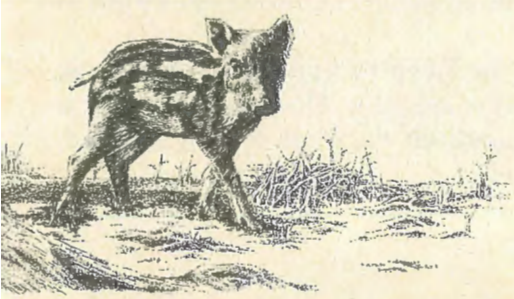
The farm colubrids range in size from a scarce red-bellied *Storeria* that creeps about in leaf mould and matures at a length of five inches to the handsome gun-metal indigo snake that can swallow a rabbit. The rear-fang contingent—the typical snakes that have independently devised poison fangs in order to get food—is represented by the crown snake, *Tantilla*, which has grooved



fangs but is too small to get a grip on a human. You can dig up a scarlet snake a foot underground, or chase a coachwhip over many acres, or see a slender twig on a bush turn into the air-thin grace of *Opheodrys*, the rough green snake. Most of the typical snakes on the place lay eggs, but some bear their young alive. Some eat any living prey they can catch and swallow, but the hognose snakes rely mainly on toads for food, the king snake eats other snakes, and the red-bellied, shiny horn snake in the pond eats mostly salamanders.

The remaining snakes of the farm and of the world constitute two groups among which the production and injection of venom have become highly refined adaptations. These are the vipers and the cobras, the latter group including the coral snakes and sea snakes. The cobras and their relatives (family Elapidae) are found around the world in tropical regions. They kill prey by venom injected through fixed hollow or grooved fangs situated towards the front of the upper jaw. They are generally slender as compared with vipers, and except for one Australian species their heads are not markedly broadened or heart-shaped. Some of them, like the mambas of Africa, are big, swift, obstreperous and even warlike. Others are timid burrowers or foragers in leaf mould, like most of the American coral snakes. The king cobra of India with its frightening hood reaches a maximum length of about 18 feet, but some of the burrowing elapids may be only a few inches long, with a gape of mouth too narrow for biting people. In Australia, the cobra-like snakes by far outnumber the typical snakes. There is a fantastic variety of species there, including such creatures as the dreaded tiger snake, the death adder and the 12-foot taipan, perhaps the most ferocious snake in the world when provoked.

THE poisonous snakes with the most elaborate venom-injection apparatus are the vipers (family Viperidae). They are found on all the continents except Australia; in fact, most poisonous snakes of temperate regions are vipers. There are two well-marked groups of them: the true vipers (sub-family Viperinae), confined to the Old World; and the pit vipers (sub-family Crotalinae), which have both American and Asiatic members but are mainly concentrated in the New World. Most vipers are stout-bodied snakes with the wedge-shaped or heart-shaped head generally thought of as the mark of a poisonous snake. The pit vipers include such imposing animals as the rattlesnakes and the tropical American fer-de-lance and bushmaster. Their name is derived from a sensory depression, or pit, in the side of the snout between the eye and the nostril. This is elaborately supplied with nerves and blood vessels and is an organ specialized for detecting the presence and range of warm objects. Most pit vipers eat warm-blooded prey, and the pit is no doubt used primarily in feeding, but like the rattle of the rattlesnake it is perhaps also of value as a means of avoiding injury under the hoofs of big mammals.



A GIANT SCAVENGER

The Komodo "dragon", named after the East Indian island where it was first found, is the largest living lizard. A voracious and undiscriminating carnivore, it will eat any kind of carrion, as well as living animals. Lethargic when it has fed, this monitor lizard shows surprising spurts of speed when hungry, and uses its long, strong tail with lethal dexterity.

The only way my farm stands out in the serpent-rich north Florida landscape is in the prevalence of poisonous snakes there. A coral snake on the lawn is no great event at all. Cottonmouth moccasins come up from the pond—every now and then the cook kills one at the kitchen door. Diamondback rattlesnakes are abundant, and pygmy rattlers turn up occasionally underfoot. In fact, a snake found in the garden is almost if not quite as likely to be venomous as harmless, and this is by no means the case in most places.

We have had five children ranging the premises for a dozen years and they have to date remained unbitten. The only trouble we have had with snakes has been their killing of our dogs. A series of short-legged dogs has lived on the place, trustful bassets and testy dachshunds opposed to all forms of life not canine or human. Of these, three, and perhaps four, have been killed by snakes.

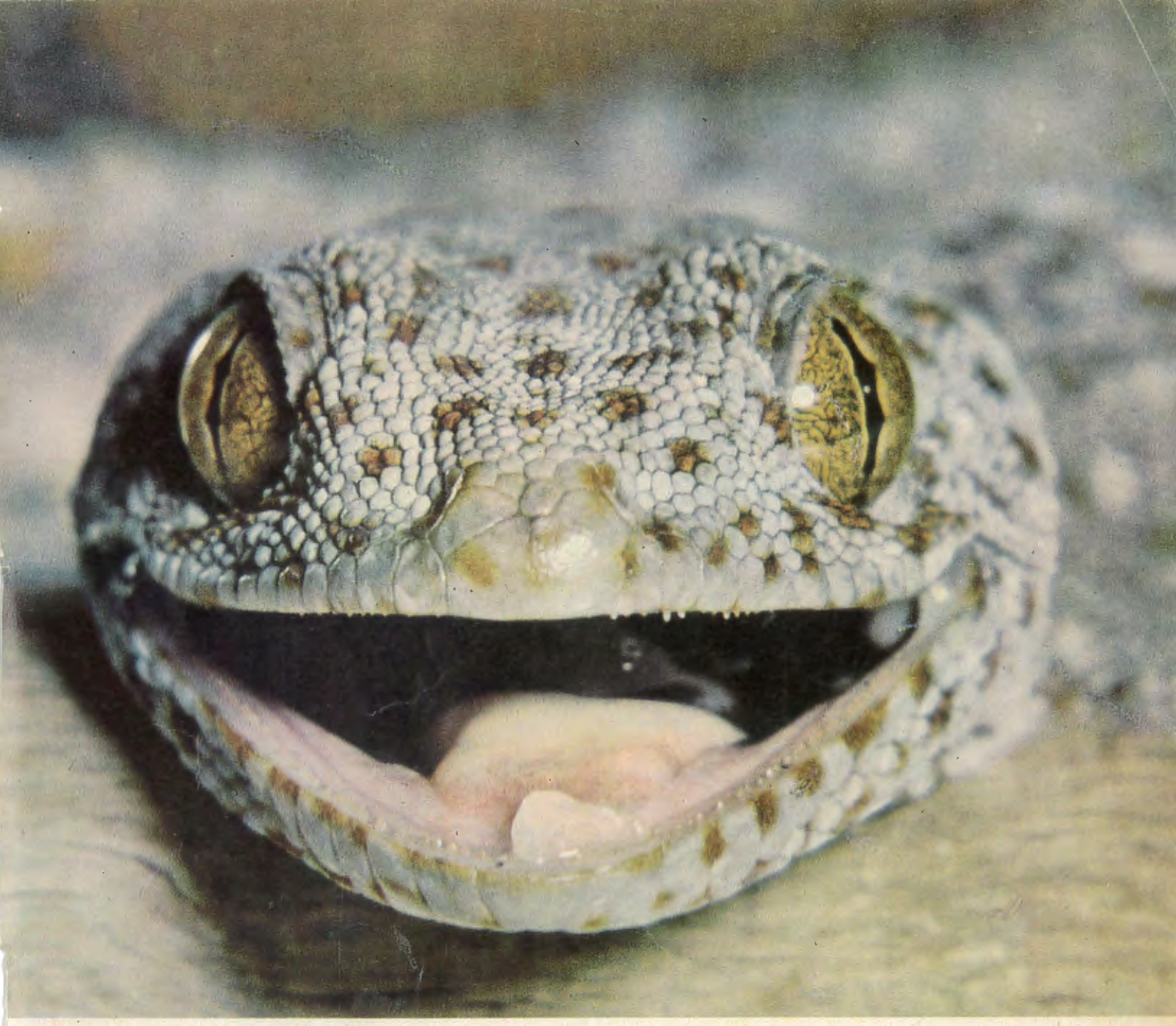
LIKE any proper Florida pond, ours has an alligator in it. Alligators belong to the order Crocodilia, the third major group of reptiles, which includes three living families. One of these, the Alligatoridae, has in it the familiar American alligator, its close relative the Chinese alligator and the various tropical American caimans. The second family is the Crocodylidae, the true crocodiles, dwarf crocodiles and the false gavial. The third, the Gavialidae, has a single living representative, the slim-jawed, fish-eating gavial of southern Asia.

Crocodilia are in some respects the most advanced of reptiles. They share with higher vertebrates a four-chambered heart. This makes possible a more efficient circulation than other reptiles have, because in the usual reptilian three-chambered heart there is some mixing of newly oxygenated blood from the lungs with the de-oxygenated blood just in from the tissues of the body. Another advanced feature of crocodilians is a partition between the cavities of the chest and abdomen that suggests the diaphragm of mammals. In crocodilians the cloacal opening is a longitudinal slit as in turtles, instead of being transverse as in lizards and snakes.

Full-grown crocodilians range in size from between three and four feet, in the case of the Congo dwarf crocodile and the dwarf caiman, to top lengths of about 23 feet in the Orinoco crocodiles. The biggest American alligator ever measured was slightly over 19 feet long. How long crocodilians live is not certain, although they have long been thought of as practically indestructible creatures that live for ever. In the rare places in which they are not killed long before that by man they probably do reach ages of 50 years or more. They appear to mature at an age of six or seven years.

Crocodilians have one of the few well-developed voices among reptiles. In its timbre and impact on the surroundings, the voice of the American alligator must be considered one of the great animal voices of the world. It is a matter of family pride that the alligator which nearly a decade ago appeared at a tender age in our pond finally began to sing. For six years he had cruised silently about, methodically eating or driving off other alligators that came in from other places, and cracking mud turtles with a ghastly noise that disgusted my daughter. Then one misty morning he came forth with the earth-shaking, soul-stirring song of his kind. I suppose this means he is growing up. Or she—the females bellow too.

The remaining order of living reptiles, the Rhynchocephalia, has one living representative. This is the tuatara, *Sphenodon punctatus*. There are no tuataras on our farm. They live only on a few islands off the coast of New Zealand, and their story will be told in a later chapter.



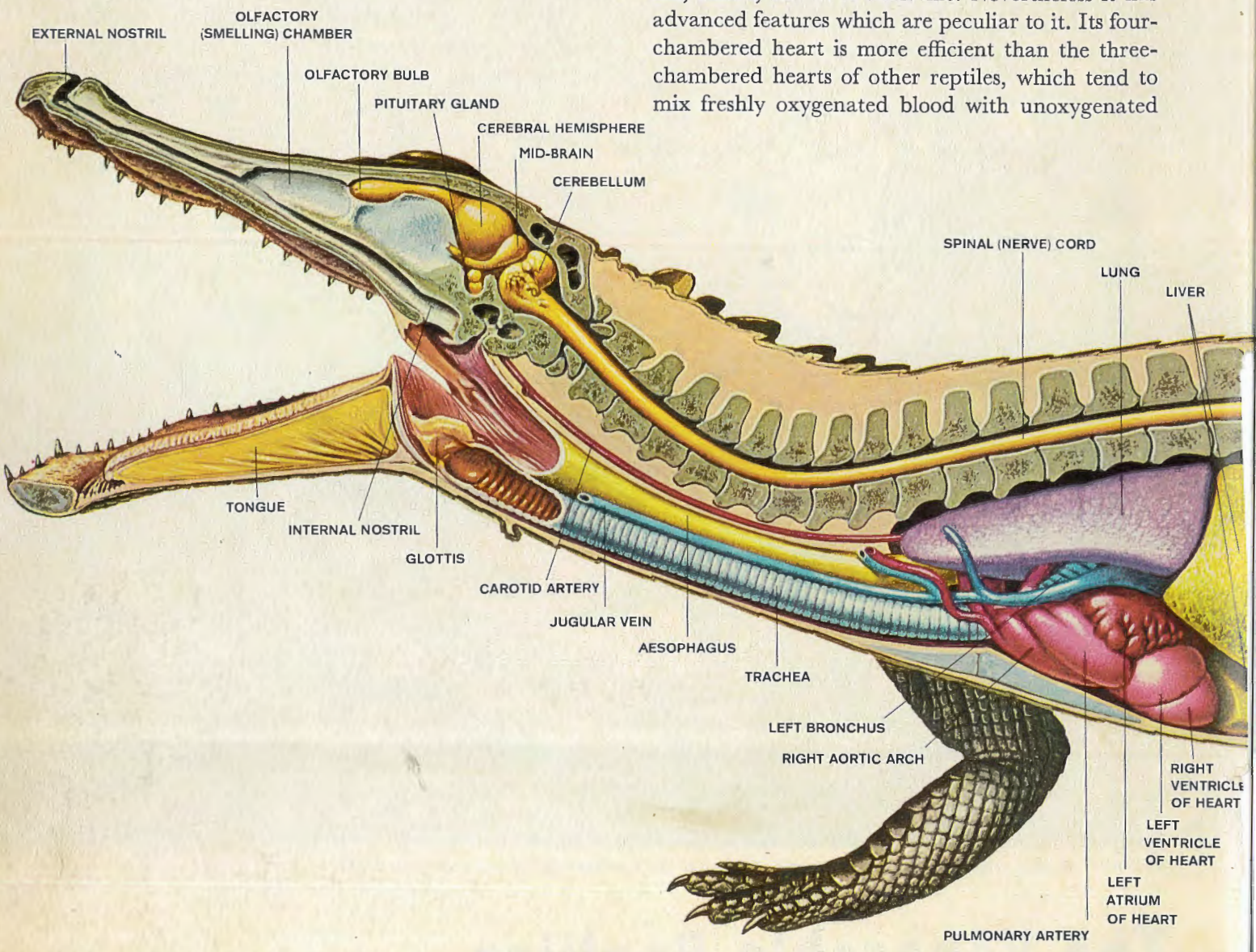
THE TOKAY GECKO, A FOOT-LONG LIZARD OF ASIA, IS ONE OF THE FEW REPTILES TO LIVE WITH MAN—IT IS AN EXPERT INSECT CATCHER

The Venerable Reptiles

Once the dominant form of life on earth, the reptiles are now vastly reduced in numbers and variety. They persist today in three main groups—the turtles, the lizards and snakes, and the crocodilians—plus one almost extinct form, the little-known tuatara. Many are relatively unchanged from the age when dinosaurs dominated the land, and offer fascinating hints as to what life was like then.

The Anatomy of a Reptile

Although no single reptile can be considered typical of all reptiles, the alligator is as good a representative as any, since it has a backbone, is cold-blooded, lays eggs with shells and has a reptilian skin—i.e., slated, scaled or shell-like. Nevertheless it has advanced features which are peculiar to it. Its four-chambered heart is more efficient than the three-chambered hearts of other reptiles, which tend to mix freshly oxygenated blood with unoxygenated



MOUTH. To achieve its characteristic gape, the alligator does not merely drop its lower jaw but raises its head and upper jaw. The teeth are used for seizing and holding prey—not chewing.

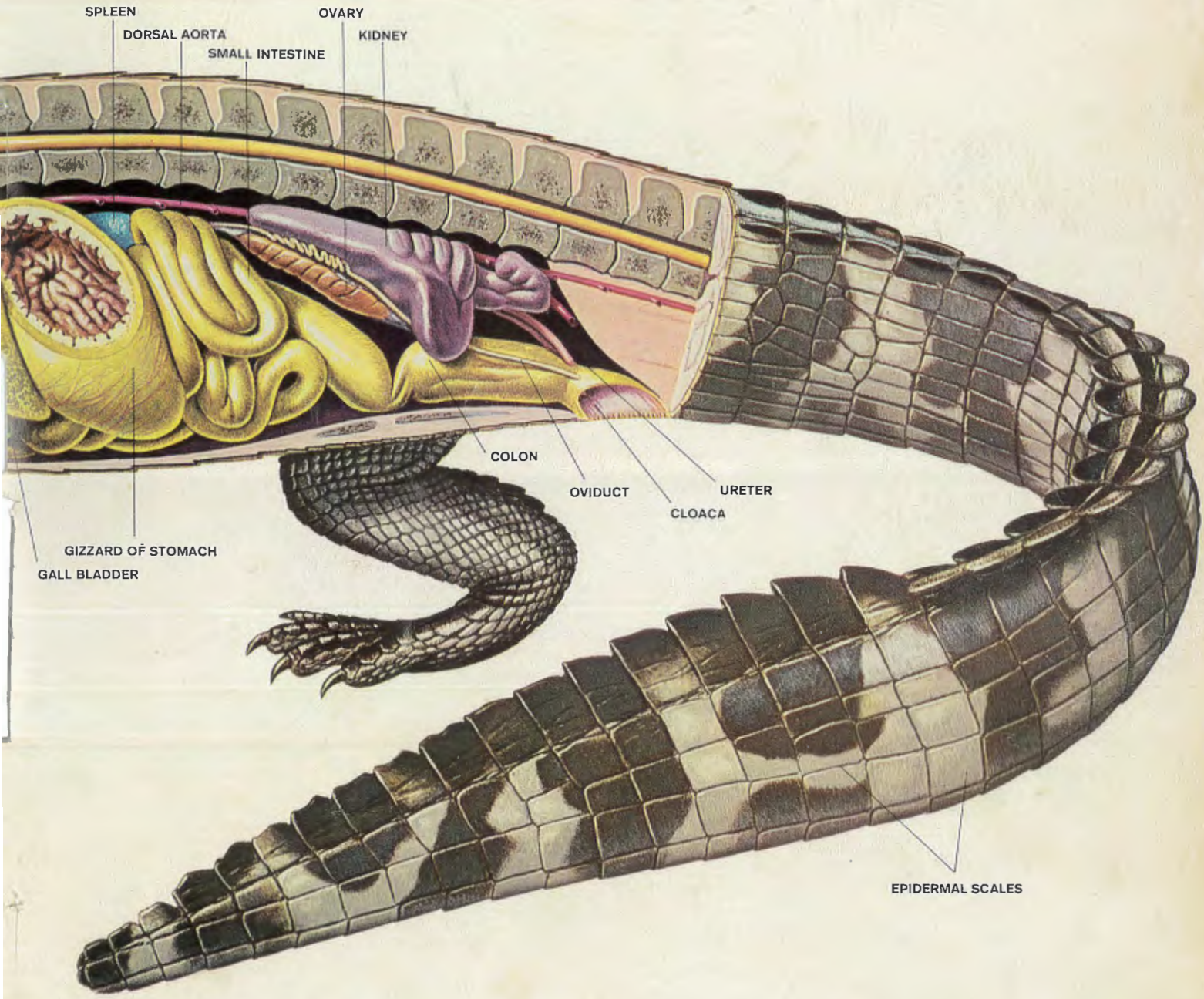
STOMACH. Because an alligator cannot chew, its stomach has two parts—a muscular gizzard and a digestive section. The gizzard's grinding of food is aided by swallowing hard objects.

HEART. Blood passes from the right ventricle through the pulmonary artery for oxygenation by the lungs; it returns through the left atrium to left ventricle, and is pumped out to the body.

SCALES. The alligator's armour is composed of horny scales, each developing on its own and replaced by layers from below. Those shielding the back and tail have bony plates beneath them.

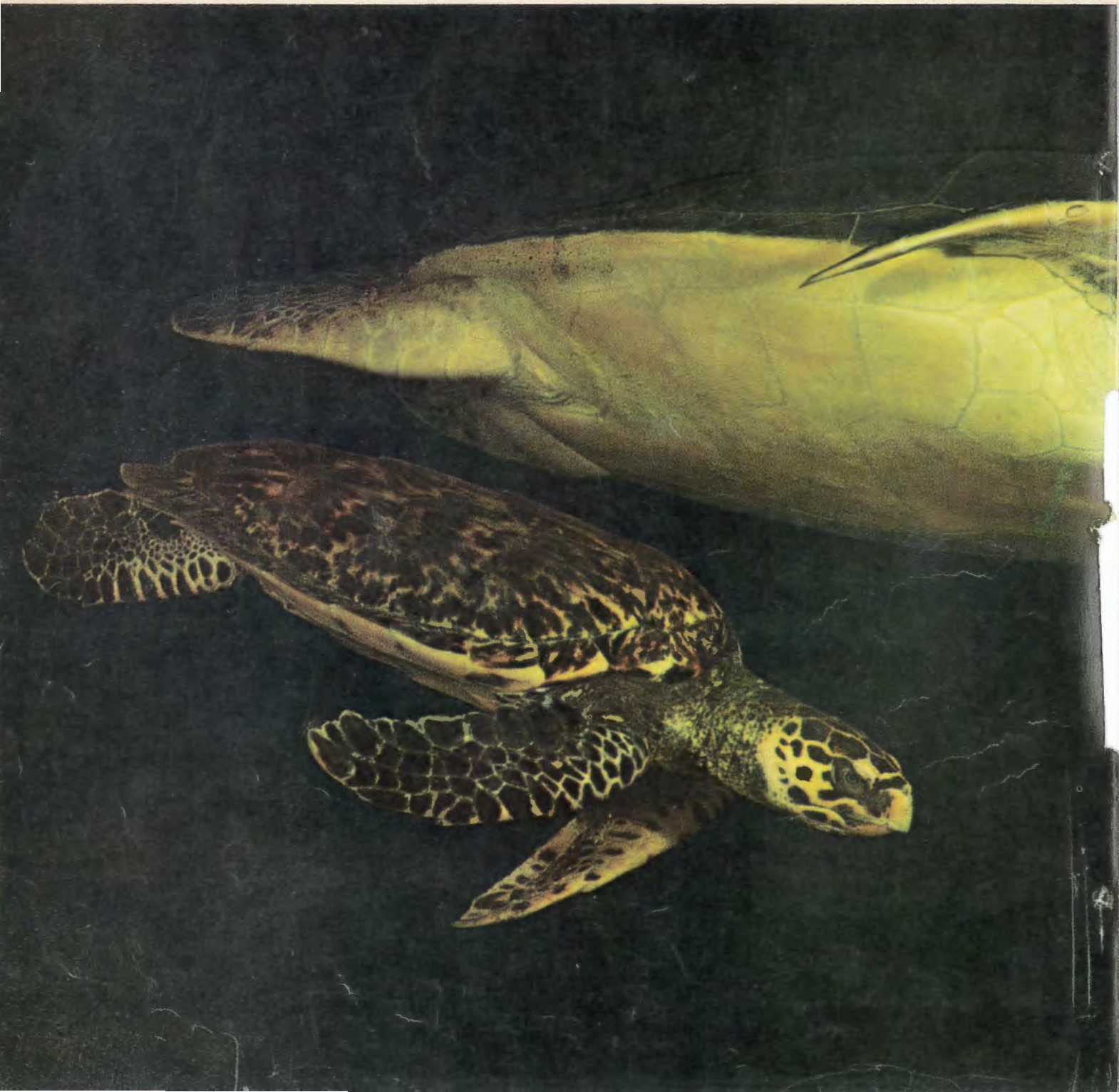
blood. Its respiratory system is better. The nostrils are separated from the mouth by a hard palate. When the alligator swallows a struggling victim there is no danger that a desperate kick will penetrate the roof of its mouth and damage its brain. The alligator has well-developed lungs in comparison to the more primitive sac-like structure of snakes. It has the most highly developed brain of any reptile, and is one of the few to have its teeth firmly set in its jaws.

On the other hand, the alligator lacks a well-developed Jacobson's organ, which means that its ability to detect tastes and odours is not nearly so acute as a snake's. It has the well-developed digestive system which works so efficiently for all reptiles, but lacks a bladder, although most turtles and lizards have one. Its ammoniac kidney wastes, along with intestinal wastes, pass through a chamber called the cloaca which opens to the outside of the body.



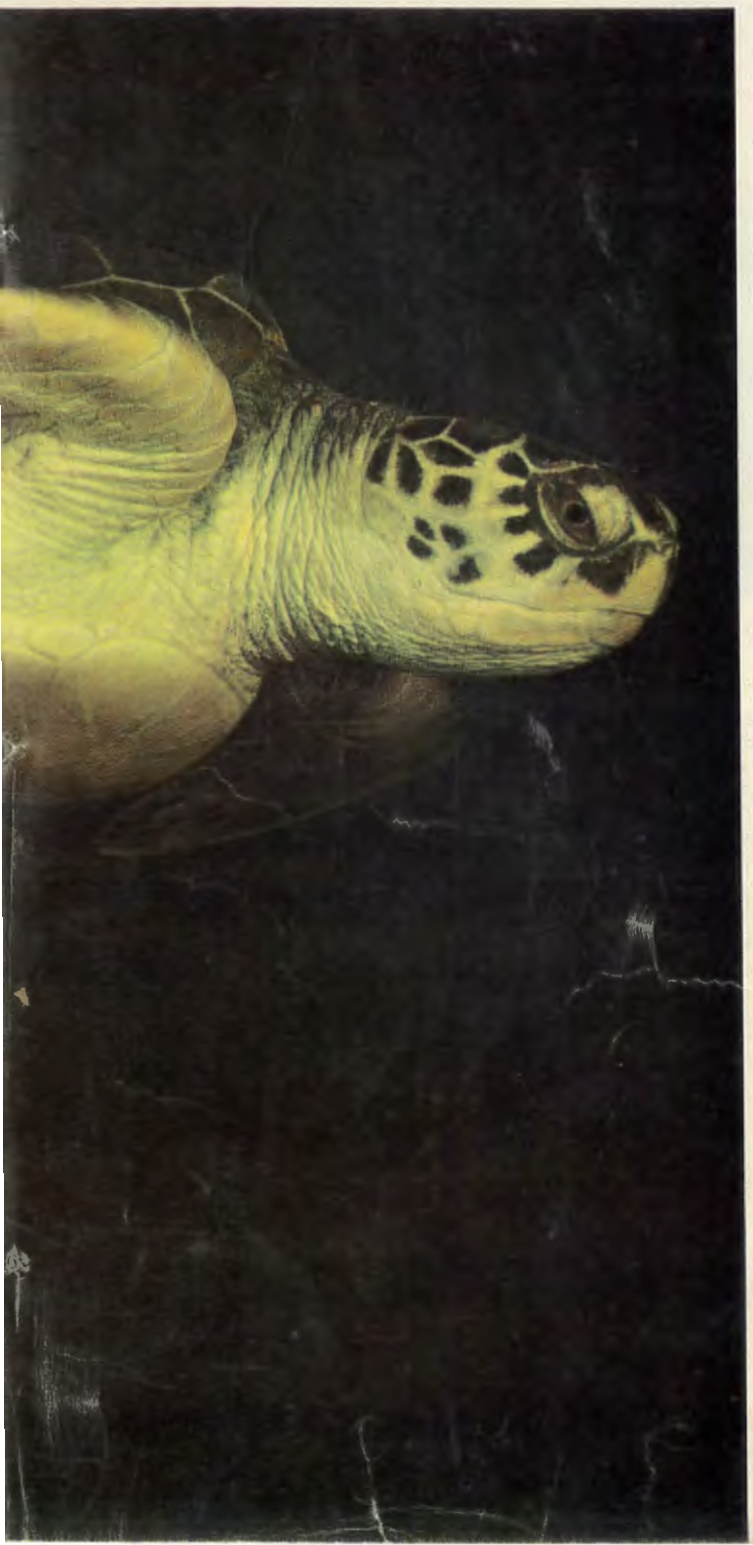
The Tenacious Turtles

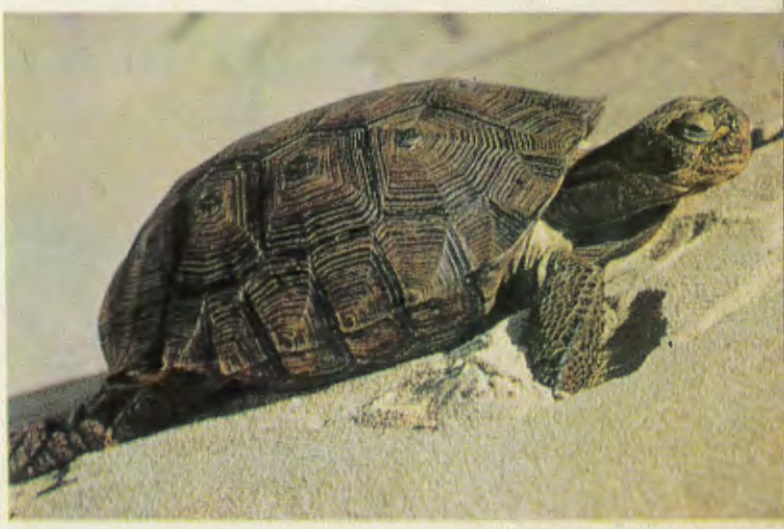
Clumsy object that it is, the shell has helped to ensure the survival of the turtles for 175 million years. Today it is still worn by all species, although it has been modified to suit a variety of environments. Sea turtles, for example, have jettisoned much of their shell bone and are among the fastest-moving of modern reptiles. Land turtles have thinned theirs down to make locomotion on their elephantine feet less ponderous. Soft-shelled turtles, which live in fresh water, have developed pancake-shaped shells with flexible edges which they use to help to bury themselves. Lying hidden in shallow water, waiting for prey, they occasionally crane their long necks to breathe air with their snorkel-like nostrils. Some-



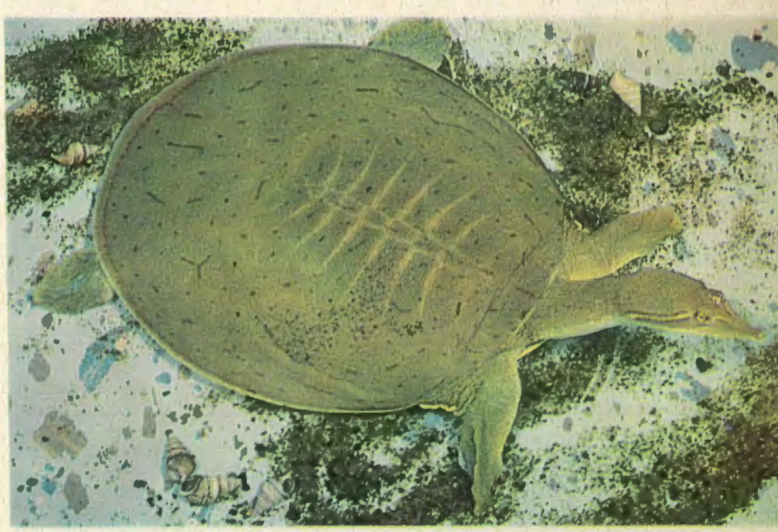
times they remain submerged for several hours, extracting sufficient oxygen from the water they pump in and out of their pharynges. Recent studies have revealed that turtles can survive for long periods without taking in any oxygen from the outside.

Turtles are believed to be quite hard of hearing. Although they have well-developed middle and inner ears, and although some have voices, the latest evidence is that they hear only sounds of low frequency. They rely instead on their skins and shells to pick up vibrations from the ground or water. They can live a year or more without eating. Some females, in the most amazing feat of all, can produce fertilized eggs as long as four years after mating.





THE DESERT TORTOISE, found in the American south-west, is protected against loss of moisture by its shell and uses its burrow less as a retreat from danger than as a place to cool off.



THE SPINELESS SOFT-SHELLED TURTLE of the central and south-western U.S. can hide in the beds of rivers, streams and ponds by shuffling its leathery-skinned shell into sand or silt.

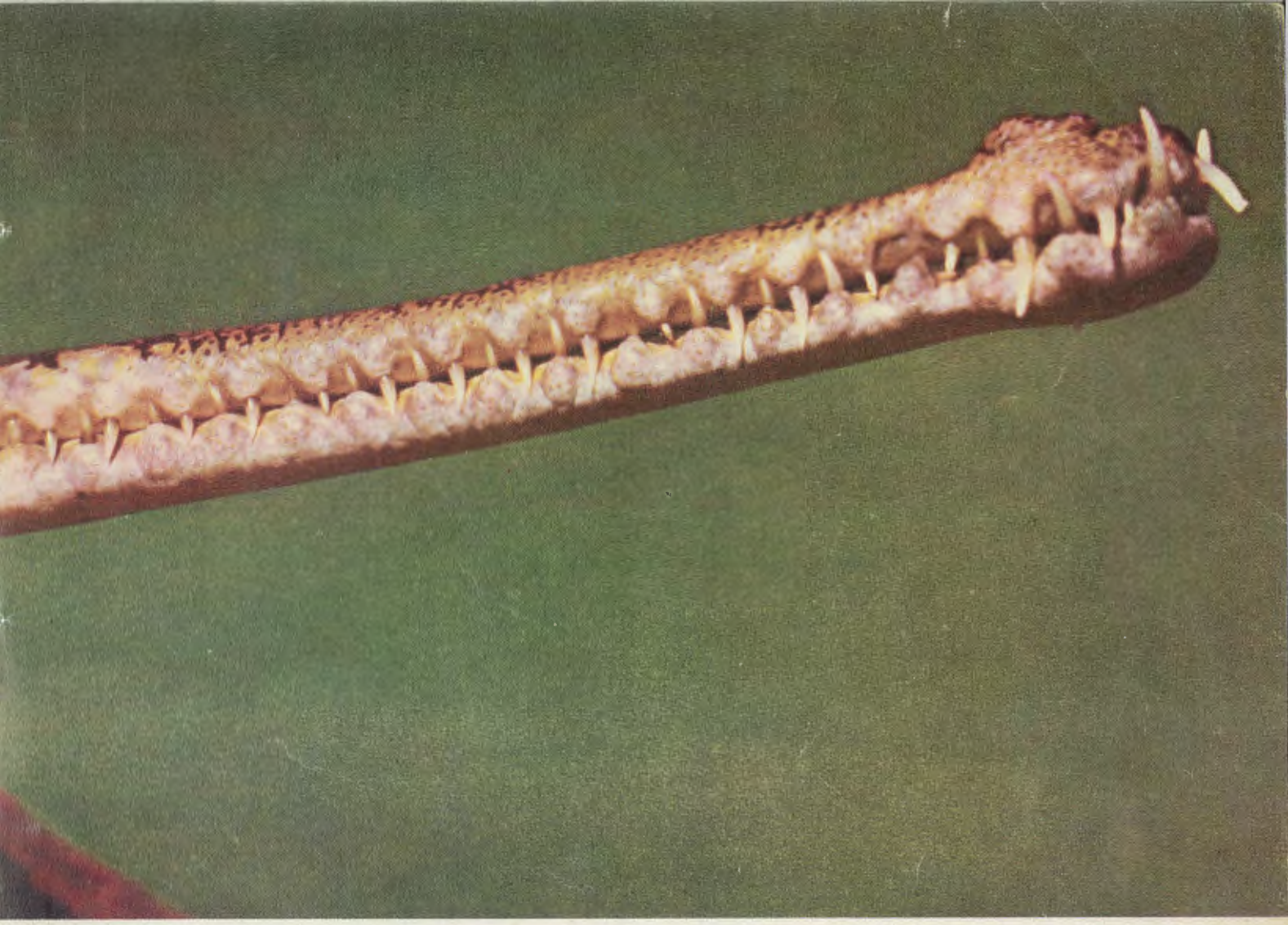
A HAWKSBILL AND A GREEN TURTLE, dwelling in the warm seas, show aquatic adaptations—lightweight shells and paddle-like legs. They swim with bird-like flaps of their front flippers.

THE GAVIAL OF INDIA, WITH A RECORDED MAXIMUM LENGTH OF 21.5 FEET, HAS THE NARROWEST SNOUT OF ANY CROCODILIAN AND USES IT

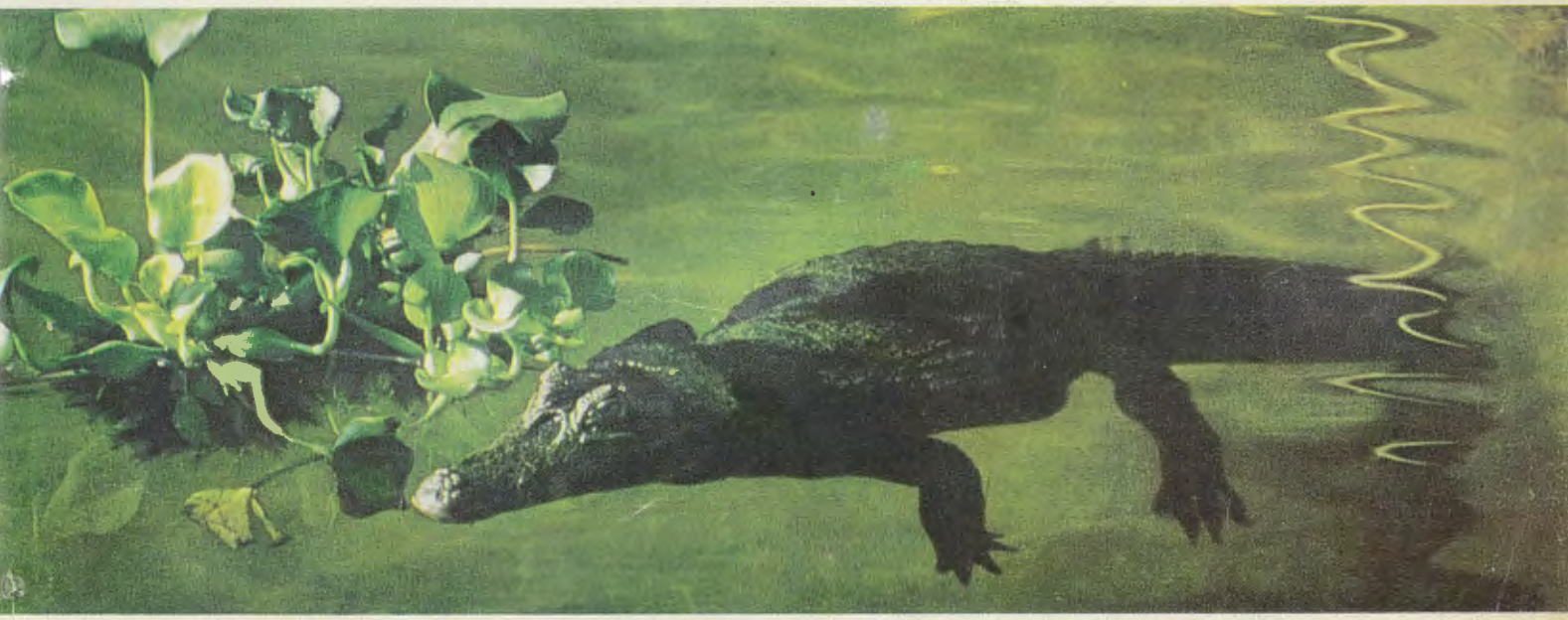
THE AFRICAN CROCODILE, one of the largest of crocodilians, grows 16 feet long. The adult feeds on fishes, mammals and other reptiles, including its young—and is a notorious man-killer.

The Huge Crocodilians

The crocodilians—the heavily armoured crocodiles, alligators and gavials—are the largest of the modern reptiles and the last surviving reptilian descendants of the stock that also produced the dinosaurs. Although somewhat clumsy out of water, they are superbly equipped for living in it. They are strong swimmers, and experts at drifting along on the surface, submerged except for their bulging eyes and nostrils, their long flat jaws not even making a ripple in the water as they stalk turtles, swimming birds and fishes. The larger crocodiles can sometimes get close enough to animals on shore to sweep them—and humans—into deep water with their tails. Crocodilians have valves in their ears and nostrils to keep water out. Because their mouths lack lips and thus do not shut completely, two palatal flaps cover gullet and windpipe during dives.



TO LASH SIDEWAYS AT FISHES. DESPITE ITS OVER-ALL FIERCE LOOK, IT IS A TIMID ANIMAL AND USUALLY RETREATS AT THE SIGHT OF MAN

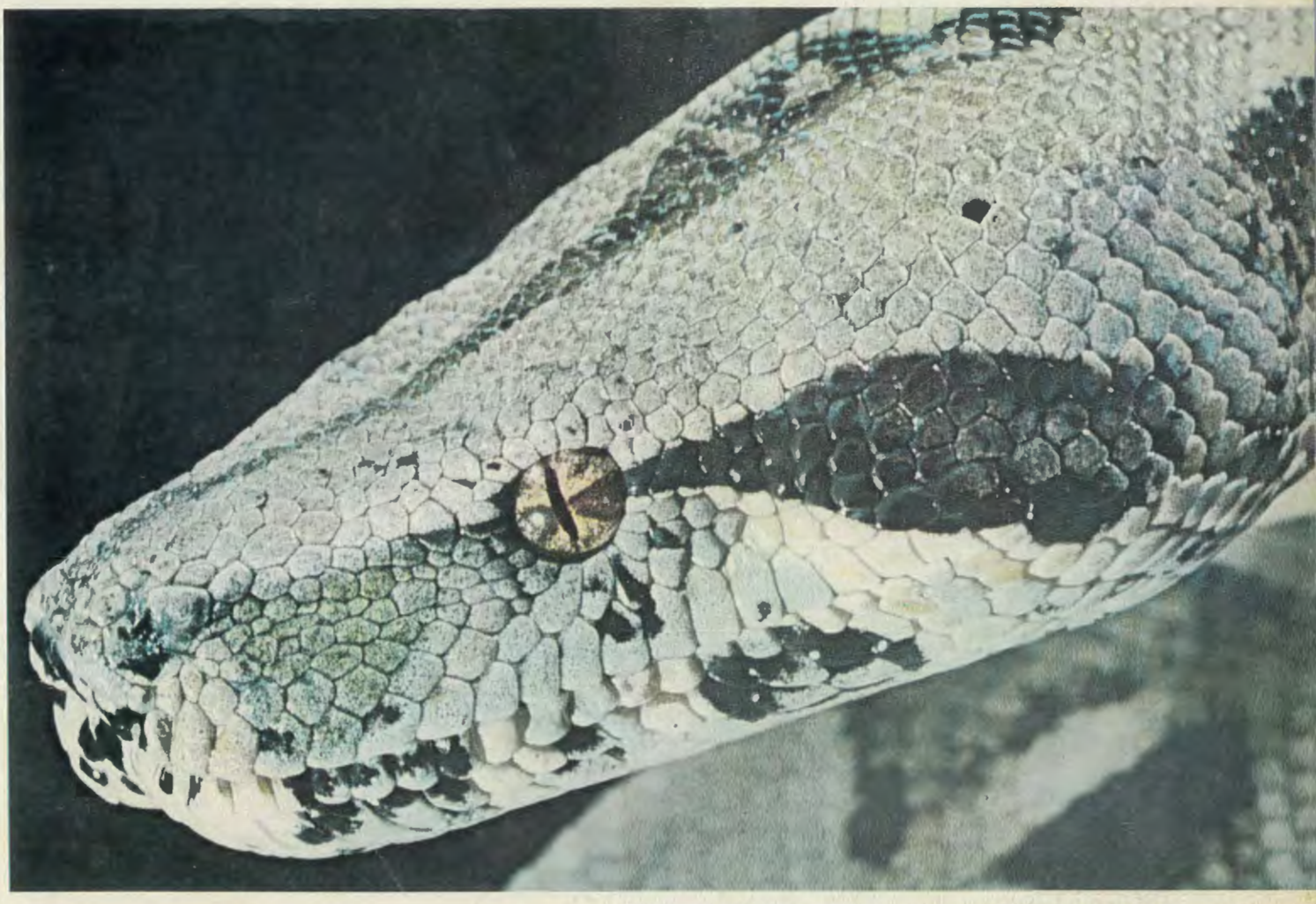


THE SOUTH-AMERICAN CAIMAN, a 6-to-12-foot relative of the mild-mannered American alligator, is the fiercest biter of the crocodilians, and even as a hatchling will display its close-set teeth. It is also the noisiest, with a repertoire of sounds ranging from growls and croaks to snorts and snuffles. During the mating season or when wounded, it lets out thunderous roars.

The Agile Snakes

All 2,700 kinds of snakes tend to look alike—long, writhing and legless. But despite this superficial resemblance, they show just as much variability of form as their ancestors the lizards do. They range in size from the five inches of a burrowing snake no thicker than a goose quill to the 30 feet of an Asian python over 300 pounds in weight. And with these variations go others—environmental adaptations such as the prehensile tails of many of the arboreal snakes, or skin colours and patterns that match or blend with the surroundings. The amazing thing about snakes is that being legless has not proved to be a hindrance to locomotion, but an enhancement, making them extremely agile. Some snakes can even out-distance a man in brush or over rough ground.

THE EYELASH VIPER, a poisonous snake of Central America, can wind its prehensile tail several times around a branch and grab at birds with its open mouth while dangling in the air.



THE BOA CONSTRICTOR, one of the most beautiful snakes, has a skin pattern harmonizing with shadowy jungle backgrounds. Dark stripes disrupt the head outline, and one disguises the eye.

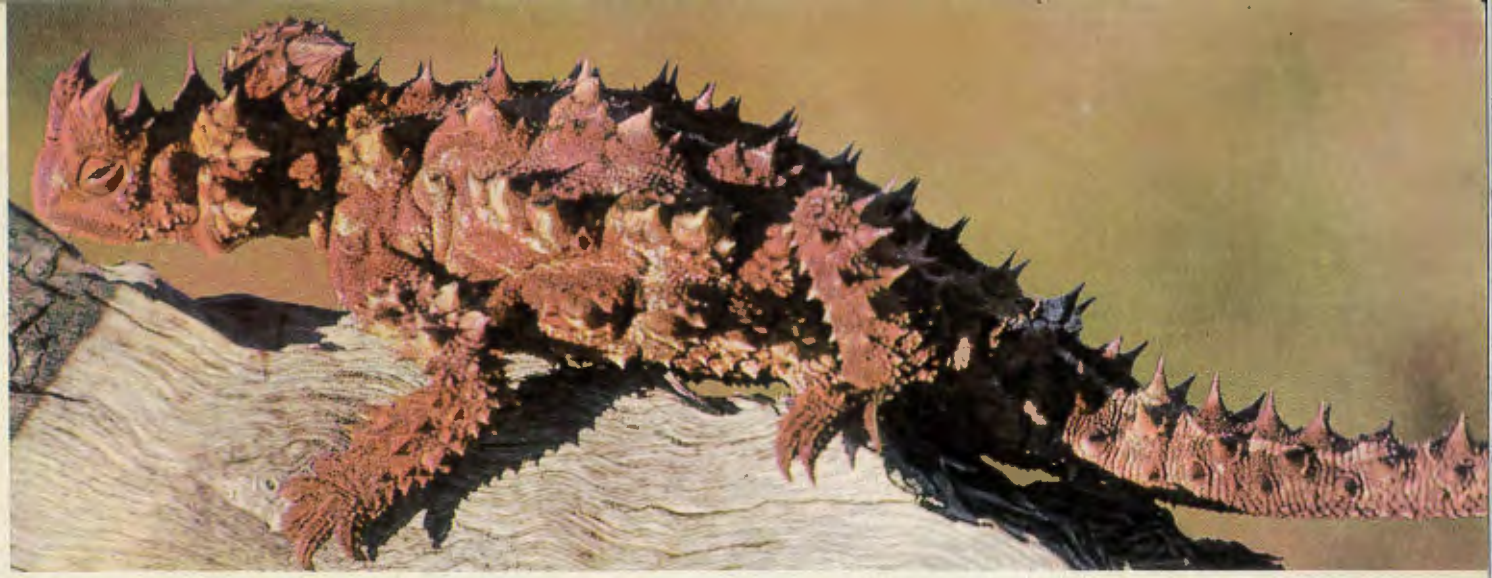
THE GREEN TREE SNAKE, coloured to blend with Central America's foliage, reaches a length of four feet, but is so slender that it can slither along branches without weighing them down.

THE KOMODO MONITORS of Indonesia, the largest, heaviest lizards, grow to 10 feet and weigh up to 300 pounds. They occasionally catch small deer or pigs and can swallow them whole.

The Dexterous Lizards

There are about 3,000 species and sub-species of lizards, and though they differ in many ways, they have one habit in common—all shed their skins. Adults moult once every month or so, during the months in which they are active, and, unlike snakes, most do not loose their epidermis in one piece, but in patches or even a scale at a time. The banded gecko below rips off its old skin with its mouth and swallows the strips. And to peel its feet, it tugs at each digit as though removing a tight glove.

THE BANDED GECKO OF MEXICO BELONGS TO A LARGE FAMILY OF AGILE LIZARDS THAT IS MOST PREVALENT IN THE TROPICS. THIS LIZARD



MOLOCH HORRIDUS, named after an ancient god propitiated by child sacrifice, is covered with stubby spines and has two knobs over its eyes, which increase the size of its head. But despite its fearsome name, this Australian lizard is only eight inches long, moves slowly and deliberately, and subsists on a diet of ants, consuming from 1,000 to 1,500 at a single meal.

COMES OUT ON TO THE DESERT FLOOR AT NIGHT TO HUNT INSECTS AND TWITCHES ITS TAIL IN CAT-LIKE FASHION JUST BEFORE LUNGING AT ITS PREY

A WORM LIZARD from Florida so resembles an earthworm in both form and locomotion that it is often mistaken for one. Blind and without ear openings, it tunnels through damp soil, where it feeds on ants and termites. When exposed under a log, the foot-long worm lizard may slide backwards into the burrow or use the calloused, blunt end of its tail to plug the opening.

A TINY SPUR, one of two located on each side of an anaconda's vent, is a vestigial leg. The male uses these movable spurs to scratch—and probably stimulate—the female during courtship.

Snakes with "Legs", Lizards Without

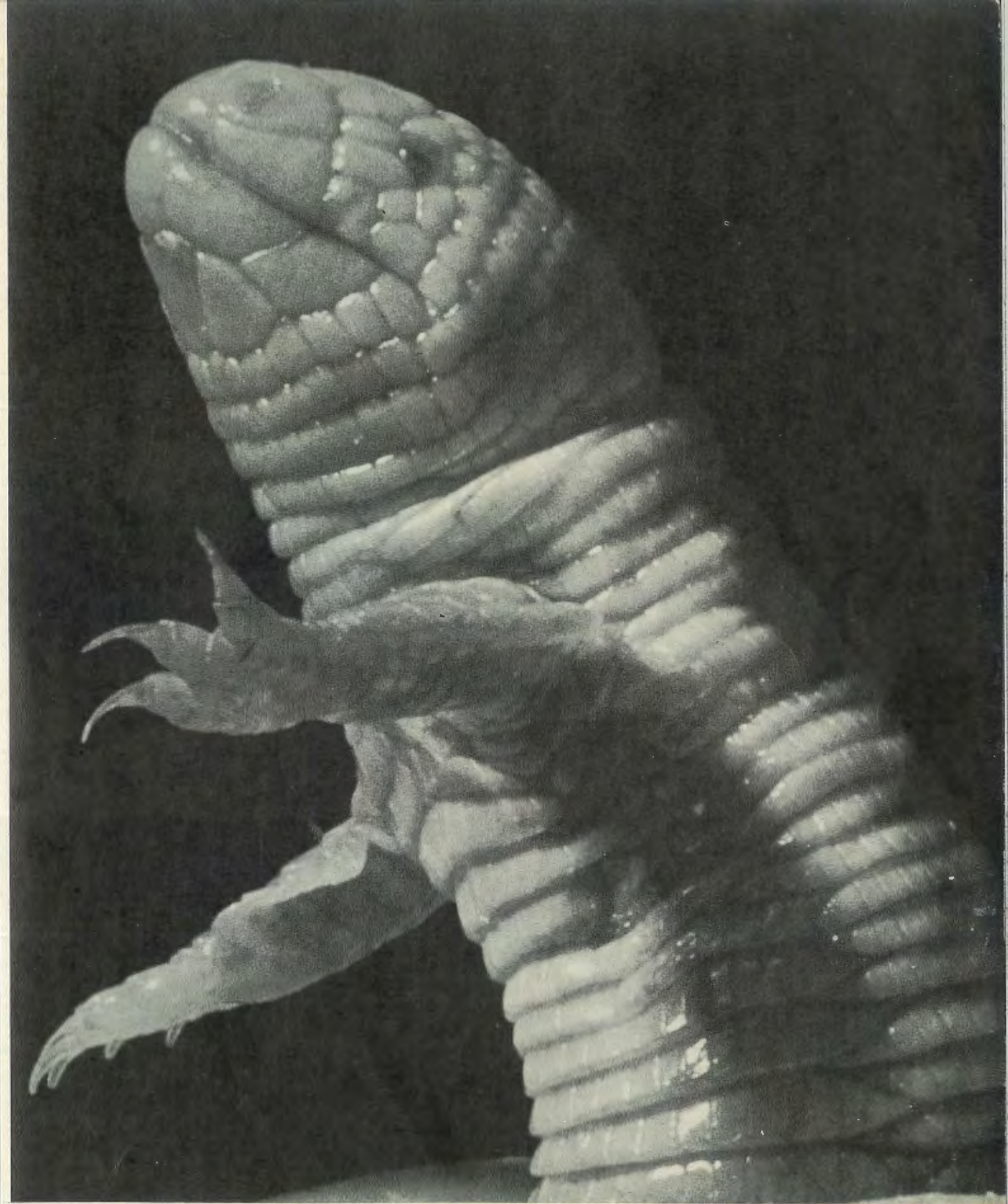
Lizards are thought of as having legs and snakes as being legless, but this is not always strictly true. Such snakes as the anaconda, the boa constrictor and the python have vestigial hind legs which they no longer use for locomotion but can still move freely. The worm lizards, with the exception of three species, lack limbs, having lost them in the process of becoming burrowers. They live underground, mainly in the tropics, and tunnel through the earth with their heads. Their skulls are specialized for the task, with brain cases that are almost entirely enclosed and snouts that are often shovel-like, as in the eyeless worm lizard on the left. Other results of life underground include a soft, pale skin folded into rings, shielded eyes reduced in size, a short tail and a left lung much bigger than the right one.

THE HEAD OF THE AJOLOTE, SMALL IN COMPARISON TO THE THICK BODY, HAS TINY EYES BENEATH THE SKIN AND IS WITHOUT EXTERNAL EARS

A Rare, Two-Legged Lizard

The ajolote, the two-legged worm lizard of Mexico's Baja California, is one of America's rarest reptiles. Until recently, when 11 wriggling specimens were presented to the San Diego Zoo, little more was known about it than that it lived underground in burrows and came out only at night. Its stout, clawed feet suggested that it might be able to crawl overland.

Just why the ajolote and two related Mexican species should have front legs, unlike all other legless worm lizards, no one is yet able to say. Some authorities suspect that these three species are the least specialized of their family and therefore still in the evolutionary process of reducing and eventually losing their limbs completely. The ajolote uses its legs principally for burrowing in the ground, and though they are only a twentieth of its total length, they still help it a bit in crawling over hard surfaces, with additional thrust supplied by serpentine or caterpillar movements of the trailing body.



MOLE-LIKE CLAWS of the ajolote are used for digging hard-packed soil, but when the earth is soft they are folded against the body and the blunt head does much of the work, twisting from side to side in an almost circular motion and pushing forward. The soft skin covering the legs and the underside of the body is so transparent that the blood vessels often show through.

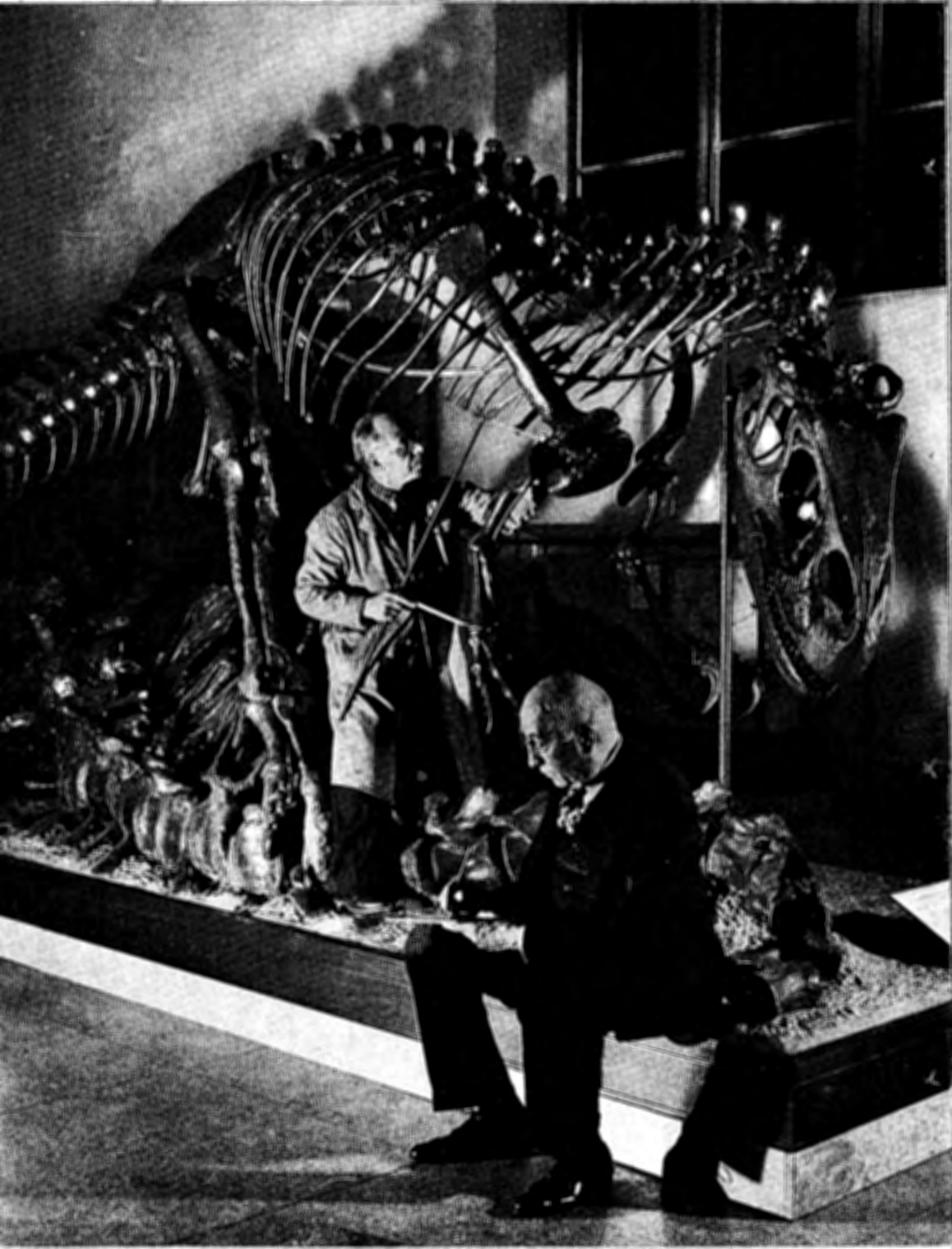
Lone Survivor of the Past

Sole living representative of the rhynchocephalians, a once widespread group of "beak-headed" reptiles, the tuatara has managed to survive for 200 million years with only minor evolutionary changes in its skeleton. When it first came to the attention of scientists in 1831, it was identified as a lizard, which it superficially resembles, and a quarter of a century passed before a study of its anatomy revealed its uniqueness. Today, with its range limited to 20 small islands in New Zealand, the tuatara is the subject of extensive research and attempts are being made to find out why it did not disappear ages ago along with all its relatives.

The tuatara grows at a slow rate and probably does not reach sexual maturity until it is at least 20 years old. This would seem to make it one of the longest-lived of animals, and suggests that some of the full-grown males may be over 100 years old. Its eggs are believed to be fertilized nearly a year before being laid and take about 15 months to hatch —much longer than those of most other reptiles.

LAST HOME of the tuatara is two groups of very small New Zealand islands shown here by arrows and areas in solid colour.

A BRIGHT-EYED TUATARA emerges from a hole under the roots of a small tree. Often the tuatara shares a petrel's burrow with the bird itself—and sometimes with the bird's eggs or young.



AN ALLOSAURUS skeleton is measured by two palaeontologists at New York's Museum of Natural History. It was the largest meat-eating dinosaur of the Jurassic, a 30-foot-long, two-ton denizen of the lowlands.

2

The Golden Age of Reptiles

No student of the history of life on earth will deny that the coming of the reptiles was one of the great events. As the first truly terrestrial vertebrates, the early reptiles not only appeared in diverse and arresting ways during their own heyday, but they also set the stage for later dramatic happenings like the rise of the dinosaurs, the beginnings of birds and the age-long evolution of the mammal line.

The reptiles went ashore during the Permian, more than 250 million years ago. There was growing opportunity in the Permian land, and by a surprising twist of history, the reptile ancestors had already evolved equipment to take advantage of the opportunity and become the first terrestrial pioneers. During the time of the coal forests, land vegetation had become well developed. Ferns, seed ferns and their kin covered the low-lying land, the energy of the sun was being caught by chlorophyll, insects had made their appearance and food was wasting on the shore. It was almost certainly the insects as a source of animal food that attracted the reptile ancestors living harassed lives at the edge of the land. If one had to work out this bit of palaeontology by logic, one would probably do it this way: the insects were there, vertebrate life was under competitive

and predatory pressure in the sea, so some of the shallow-water vertebrates, seeking food and refuge ashore, gradually acquired legs, lungs, scales and the shelled egg, and thus developed at last into land reptiles which were able to forage for insects in the forest.

The process, of course, was not quite that flowing and easily traced. There is a good deal of controversy among experts about the order in which the separate innovations appeared and what immediate selective advantage was gained in each case. One fact is clear, however. Of all the adaptations that fitted the vertebrates into their increasingly refined roles on land, none was more fundamental than the reptilian egg.

Most people, thinking of an egg, think of a bird; but they are being led astray by seeing eggs mainly at breakfast. The birds did not invent the shelled egg, they inherited it, and it has undergone no important evolution in their possession. The first shelled land eggs were reptilian, and the reptiles were reptiles only when they had evolved such an egg. The old riddle, "which came first, the chicken or the egg", is just whimsical when the chicken is a bird. But applied to reptiles the question is valid, and palaeontologists are still arguing with each other about it.

THE reptiles came from amphibian ancestors. The egg of the usual amphibian is almost naked, enclosed only by a jelly envelope. The jelly supports each egg separately in the mass, keeps out small invaders and discourages predation by larger animals, but it gives almost no protection against drying up. A typical frog egg on land on a clear day will quickly wither. Thus, no matter how far the adult frog may be able to move from water in the course of its own daily activities, when the time comes to provide new frogs most species have to go home to the water. The songs of male frogs all over the world calling the females to the ponds show how strong the obligation is.

The egg as the reptiles developed it—which was essentially as we know it today—had no such limitation. Its smooth shell tightly enveloped white and yolk. Like any egg, as it incubated it got more complex inside, and the complexity was not just in the forming body of the new animal but also in the structures required to keep the embryo alive in its shell—to keep it supported, fed, and neither poisoned nor asphyxiated.

The structures that did this are known as the embryonic membranes. They were evolved by the reptiles and kept by the birds; and, with modifications, they also serve as embryonic structures of the mammals. Because they occur both in the shelled egg and in the uterine development of the mammal, all three higher vertebrate classes—mammals, reptiles and birds—are collectively called amniotes. The name refers to one of the embryonic membranes, the amnion, which shuts in a fluid in which the embryo is able to go on leading an essentially aquatic existence as it develops. A yolk sac is held by a stalk from the belly region of the embryo, and just behind its attachment is that of the allantois, another sac which partly fills the space between the amnion and a third membrane, the chorion, which lies just beneath the shell. The allantois receives and stores embryonic waste, serving as a sort of bladder. It also has blood vessels that pick up oxygen that passes through the shell and conduct it to the embryo. The shell reduces evaporation, but it is porous and does not wall the embryo in completely. It shuts out prying small animals, for example, but not the oxygen the embryo requires to live.

For the embryo to thrive, such an egg must be kept warm and not too dry,

BY THEIR HIPS WE SHALL KNOW THEM

TYPICAL SAURISCHIAN

Although the two dinosaurs shown here have a close external resemblance to each other, they actually represent two distinct groups: the saurischians and the ornithischians. All dinosaurs belonged to one group or the other, and they are classified today by the kind of hipbones they had. The saurischian hips were quite like those of even more primitive reptile ancestors. The more specialized ornithischians developed heavier, stronger hipbones which were particularly well adapted to a four-legged gait, although each group contained both bipedal and four-footed members.

TYPICAL ORNITHISCHIAN

and must never be submerged for long in the water. Thus the shelled egg, laid on land, is a kind of private secluded pool in which a tender, developing reptile can go through its perishable stages in much the same environment its ancestors lived in. The egg itself is a terrestrial adaptation, but the animal it harbours is still aquatic.

The shelled egg is thus the essence of the reptile. No amount of protection of any animal's adult stages will allow real pioneering on shore if the embryos remain unprotected. The adult's scales reduce water loss from the body, or it can move about to damp places to avoid drying up. But an embryo starts out as a helpless cell, almost without structure and without any capacity for movement at all, and it must be protected if it is to survive.

One of the frustrating features of the fossil record of vertebrate history is that it shows so little about the evolution of reptiles during their earliest days, when the shell egg was developing. There are three fundamental body features that the earliest land vertebrates had, and it would be very nice if we could draw a neat, clear, logical picture of their development. These features are: legs, lungs, and a connection between nostril and pharynx that allowed animals to breathe with their mouths shut. Unfortunately for logic, these things were not started by reptiles, nor even by the earlier amphibians. We must go even farther back, to the fishes, to find their beginnings. In trying to account for this, alternative explanations come to mind. Either the fishes that had the structures used them for some hidden purpose lost in time; or their bearers actually did use them for what seems the obvious purpose of such an adaptation—going out on land. The latter is what palaeontologists believe. The old lung-bearing, nose-breathing, stalk-finned fishes, known as Crossopterygii, remained fishes, but they apparently acquired the new adaptations in order to survive in the uncertainty of a shore-water environment that was subject to periods of drying up. Alfred S. Romer of Harvard University some time ago made the ingenious suggestion that the first ventures ashore were perhaps not hunting trips, but more likely mud-slogging hegiras out of drying-up pools in search of better water. That is to say, the land-life equipment was at first used in search of ways to stay *in* the water rather than get out of it, at a time when the water was disappearing.

THERE is logic in this argument. There was probably no well-developed spread of truly terrestrial insects in Devonian times. Because the ancestral vertebrates are believed to have been carnivorous, they would have found slim pickings on shore until well towards the end of the Carboniferous, so it is hardly likely that food motivated these first terrestrial adaptations in the fishes in these earliest, pre-insect times.

And yet some of the early vertebrates did somehow become land-adapted. Over a great span of Palaeozoic time we find developments occurring in four kinds of creatures, and it is reasonable to try to string them together into some kind of evolutionary sequence. First there were the stalk-finned fishes, then scaled amphibia known as labyrinthodonts, then some kinds of semi-aquatic reptiles, and finally true land reptiles. These surely all belong to a single bloodline, but they overlapped in time, and the evolution to a finished land reptile was certainly not a smoothly progressive adaptive process going hand in hand with a gradual movement into the land. On the contrary, like most things in the long, slow, millennia-consuming process of evolution, it had fits and starts, blind alleys, repetitions and reversals. One theory even holds that the shelled

egg evolved in a still-aquatic animal as a protection against the hazards of larval life in the water—and no doubt the teeming shore waters of Carboniferous seas and lagoons had predators in plenty to stimulate such a move.

There is another theory about how the reptiles originated and developed the shell egg. Coleman and Olive Goin of the University of Florida recently suggested that the great advance occurred among creatures living in mountainous regions, where standing water was scarce, streams ran fast, and eggs laid in them were in danger of being swept away by the current. Aquatic eggs are usually fertilized outside the body of the female. A typical frog—presumably still following the pattern of the primitive amphibians—lays her eggs at the same time as the male releases sperm into the surrounding water. Each egg is fertilized by the winner of a little race among the sperm. In fast water there might be no winners—the sperm might all be swept away, even if the eggs were not. Internal fertilization and a land egg go together nicely, because land eggs have shells which make external fertilization impossible since the sperm cannot get through the shell. So the Goins propose that both the shell egg and the behavioural pattern that allows it to be fertilized inside the body of the female before the shell is put on may have been an outcome of evolution of ancestral reptiles under pressure to develop ways to survive in rapid water in mountainous terrain.

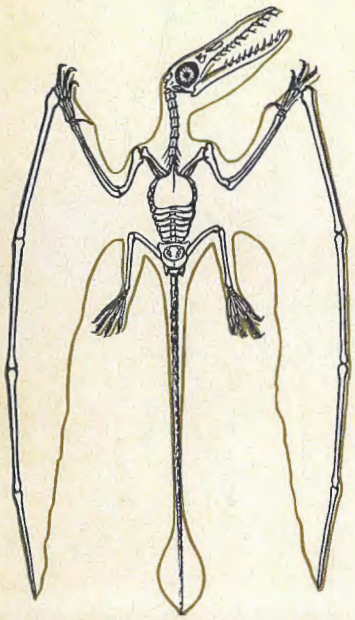
THIS theory, of course, is as speculative as any of the others, but it follows the view prevailing today that both the primary anatomical adaptations and the shelled egg were acquired while the bearers were still in the water. And speculate we must, since neither behaviour nor eggs fossilize well. But despite the trouble we have timing the separate steps towards the land, it is clear that before the Carboniferous was over, the "stem" reptiles, the cotylosaurs, had arisen. Their name derives from the fact that all later reptiles stem from them. During the Permian they diverged and set the stage for a number of important evolutionary events. They gave rise to the turtles, to the now extinct ichthyosaurs (of which more will be said in the chapter on water reptiles), to the mammal-like reptiles, from which our own line has come, and to the archosaurs, the fated creatures which would give rise to the main figures of the Age of Reptiles. For it was these archosaurs—the name means "ruling reptiles"—that produced, among others, the dinosaurs.

In a manner of speaking, as a sort of symbol of the inborn exuberance of protoplasm, no event of earth history can match the flowering of the dinosaurs. What man is doing is complicated, but man is a single, separate sort of beast, not to be compared to the dinosaurs, which were a fantastically diverse group, all of them pure, authentic animals operating under the strong hand of natural selection. To put reptiles into a decent perspective I shall have to dwell for a little on the dinosaurs. Everybody should learn about them anyway. The study of dinosaurs is good for the human soul.

The dinosaurs first appeared in the Triassic, some 200 million years ago. At the beginning they were not the giants one thinks of, but were mostly small, some no bigger than a chicken. Like a chicken, they were bipedal, walking or hopping about on their two hind legs. Though later some showed four-legged adaptations, this two-leggedness was from the start an unmistakable and typical sign of the dinosaur line.

Towards the end of the Triassic, two great orders of dinosaurs began to take shape. Their main difference was in the structure of the pelvis. The first to develop, the Saurischia, eventually came to include four-legged as well as two-

TWO MESOZOIC FLIERS



PTEROSAUR

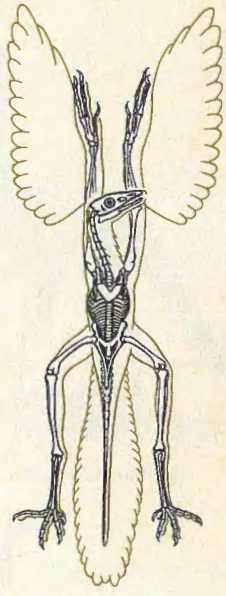
Although no reptiles can fly today, some did in the past. This long-tailed Rhamphorhynchus was one of these reptiles which took to the air some 180 million years ago. A big-jawed, toothy creature, it had an extremely elongated finger on each forelimb, providing a frame for its featherless wing. The other clawed fingers protruded for climbing. The tail ended in a rudder, aiding stability in flight. It had weak legs, probably walked little and cruised low over the water in search of its prey.

legged members, and herbivores as well as carnivores. The other, the Ornithischia, likewise had some four-legged forms, but all ornithischians fed on plants.

The biggest dinosaurs were the giant amphibious saurischians, such as *Brontosaurus*, *Diplodocus* and *Brachiosaurus*. The last named weighed some 50 tons and was the biggest land vertebrate that ever lived. In the skeletons of such animals the crushing point of bone seems to have been approached and they must have spent most of their lives partly supported by water. The most terrible carnivore was also of this order—the predaceous *Tyrannosaurus*, which reached a length of nearly 50 feet and stood, in a bipedal crouch, some 19 feet high.

During the ensuing 50 million years of the Jurassic period it was the saurischians that flourished and predominated. In the Cretaceous period that followed it, however, great changes came over both the landscape and the dinosaur fauna in it. There was widespread mountain-building and the mild tropical weather in most regions gave way to more temperate climates. Much of the tropical and sub-tropical vegetation was killed off, the flowering plants evolved and spread, and by the end of the age forest and swamp were essentially modern. In this new Cretaceous landscape the herbivorous Ornithischia flourished. If the Saurischia included the most ponderous land animals the world has known and the most terrible carnivores, the Ornithischia were surely the most bizarre. The peak of dinosaur evolution came in the Cretaceous, in the duckbill, horned and armoured dinosaurs, the iguanodons and plated dinosaurs. Some of these browsed in woods fundamentally similar to those we know today.

A Cretaceous event dwarfed by the towering phenomenon of the dinosaurs, but important to the future of reptiles, was the appearance of the snakes. The question of their ancestry is one of the most controversial problems in herpetology. They obviously came from lizards, but how? Two ideas have been advanced. The first one is that the forebears of snakes were legless lizards. This would explain the present leglessness of snakes. Equally suggestive is the difference between the modern snake eye and the lizard eye. The former gives some indication of having degenerated during its long period as an organ of the primitive burrowers, and then having undergone a burst of secondary evolution into a useful organ of sight again when its owners, the modern snakes, began spending most of their time above ground.



ARCHAEOPTERYX

The crow-sized Archaeopteryx, an ancient bird which lived towards the end of the era of flying reptiles, possessed many characteristics of the reptiles from which it sprang. Like the birds, Archaeopteryx was feathered and had strong hind limbs with claws adapted for perching. But it had a toothed, reptilian beak, claws on its forelimbs and a reptilian tail. Fossil remains indicate that the animal had a weak jaw and small teeth and, unlike the pterosaurs, probably fed on plants, insects and slugs.

INGENIOUS as these ideas are, they are disregarded by some fossil experts who have discovered significant kinships between snakes and several extinct groups of aquatic lizards, the aigialosaurs, the dolichosaurs and the mosasaurs. These, along with such surviving types as the monitors, the Gila monster and a little-known Bornean lizard, make up a group called the Platynota. Unfortunately all Platynota are, or were, either giant aquatic animals or provided with good functional legs.

Thus, the two prevalent theories of snake origin fail to fit together into a clear pattern of snake history. It would help if a subterranean, blind, limbless monitor or mosasaur could be found, but so far none has turned up. Whatever the derivation of snakes may have been, and whatever the initial value of limblessness to the early snakes, there can be no doubt that an efficient new locomotor system has taken the place of the lost limbs. When they abandoned the four-point limb support for their bodies, the early snakes also removed limits to their lengths. They allowed serpentine movements to replace footwork and this laid the groundwork for other modifications as well. Constriction—killing of prey by squeezing it—is an example. Another is the series of tree-climbing adap-

tations of arboreal species, and the concurrent advantages of having a long body that can be made to look like a twig or branch. Also, the loss of the limbs and girdles and the reduction of the cross-section of the body permitted snakes to go into places like narrow caves and rock crevices that would be closed to a four-legged animal of similar chest expansion. And for aquatic snakes the ability to swim by passing waves of undulation backwards along the body made the loss of the limbs and lengthening of the body not merely inconsequential, but actually a gain.

To the modern snakes the lack of legs is not by any means a handicap to locomotion. Although for sheer speed over smooth ground most men can move faster than most snakes, this is not true in cluttered places. Let the landscape be wooded, rough or scrubby and the snake a whip snake or racer, and a whole posse of men will be left behind in the chase.

Aerial locomotion—sustained flight—first achieved by the insects in the coal forests millions of years before, was evolved twice during the Age of Reptiles. The first venture was that of the pterosaurs, often called pterodactyls, in the Lower Jurassic. These were light-bodied archosaurs which took to the air on leathery wings stretched by their finger bones. The pterosaurs no doubt began as gliders, and some may never have acquired the ability to keep up sustained flapping flight, but others certainly did. It is believed that some pterosaurs fed on the wing, dipping fish out of the sea like modern sea birds. The biggest of them, *Pteranodon*, had a wing-spread of more than 20 feet.

ALIKE BUT UNRELATED

OSTRICH DINOSAUR

OSTRICH

Many of the reptiles that appeared during the heyday of the dinosaurs were well adapted to ways of life that later were taken over by modern reptiles, mammals and birds. Since their habits were similar it is not surprising that their shapes were too. The eight-foot-tall ostrich dinosaur, for example, was an omnivorous browser of open plains. Like the modern ostrich, it had a toothless beak and powerful legs.

IN the Jurassic, some 150 million years ago, the reptiles made a completely different approach to the problem of flight. This other plan is revealed in some famous fossils found in Germany. The oldest representative of this other kind of aerialist is known as *Archaeopteryx*. Three skeletons have been found. One is now in the British Museum, another in Erlangen and the third and best-preserved is in the Berlin Museum. The skeletal structure is essentially that of a small, spry-looking dinosaur. But by vast good luck the faithful preservation in the fine-grained Jurassic stone shows the clear imprints of feathers. A feather means a bird. Feathers, obviously derived from the scales of reptiles, are the most distinctive feature of birds, and almost their only evolutionary innovation.

There are only a few obvious differences between birds and reptiles. To answer the demands of flight, birds have achieved a constant body temperature and a metabolic rate higher than that of reptiles. For lightness some of the bones have become hollow. A breastbone has developed for attachment of the flying muscles, and bones of the forelimb have been lost or bound together to support the wing along its leading edge. The teeth and the long reptilian tail are gone. Looked at with these differences in mind, *Archaeopteryx* is a wonderful example of an intermediate creature. Its jaws were toothed, its tail was long, its breastbone was weak and all its bones were solid. Its power of flight was surely feeble; but it had feathers, and it stands as a beautifully explicit link and sign of kinship between the nightingale and the crocodile. Archbishop Ussher himself, gazing upon *Archaeopteryx*, would embrace Darwinism, and would know at once where the birds came from.

The record of the derivation of mammals from reptiles is both far longer and far more detailed than the history of birds—and also, unfortunately, it is far less clear. It begins with the pelycosaurs of the late Carboniferous—a group not far removed from the old stem reptiles. From these there radiated a great array of types known as mammal-like reptiles, and during the late Palaeozoic

and early Mesozoic these creatures were the dominant vertebrates on the land.

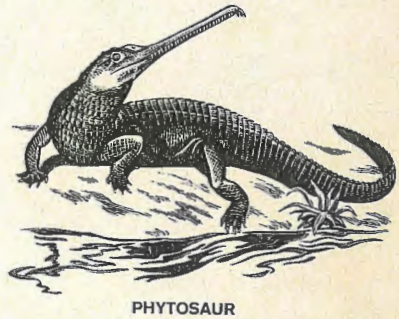
There is no missing link between mammals and reptiles, nor any single fossil type which, as *Archaeopteryx* does for birds, stands out clearly as half reptile, half mammal. If each mammalian feature could be traced to its point of origin, we might hope to put a finger on the first mammals. As it is, the case rests mostly on bones and teeth, and relying on such skeletal characters alone, we only see the ancestral forms slowly acquiring the skeleton and dentition that today we associate with mammals. We can only deduce the developing pattern of the less solid attributes not likely to be preserved in the rocks.

Fortunately there are good clear differences in the skeletons of reptiles and mammals. One such is the structure of the jaw joint. Two bones enter this joint in both mammals and reptiles, but they are different bones in the two animals. Furthermore, while in the mammal the lower jaw is a single bone, in the ancestral reptiles several bones are involved. Fossils from the late Triassic show various stages of reduction of jawbones, and a number of other traits that we now associate with mammals made their appearance at the same time.

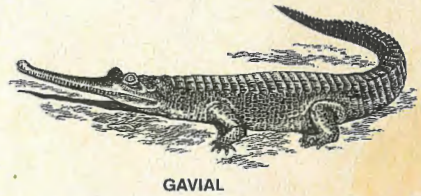
By the Jurassic there were true mammals in the world. They were all small insecure-looking creatures, and when we consider the kinds of beasts they shared the earth with we may justifiably wonder how they were able to survive at all. There could be no better illustration of the vagaries of extinction and survival. After dominating the scene for 80 million years the dinosaurs have gone, and the hairy, frisky, rat-small creatures that cowered about their feet have inherited the earth.

The Age of Reptiles is an ideal time from which to draw graphic illustrations of the three great evolutionary processes: extinction, survival and adaptive radiation, the last being the tendency for a stock of living things to evolve in such a way as to exploit all the available opportunities of its environment. From their modest beginnings in the Triassic, the dinosaur line spread and split and sent out adaptive versions of itself into endless specialized roles and niches. The whole spectrum of Mesozoic life, furthermore, shows a similar trend. But because the adaptive radiation of dinosaurs was the most spectacular show put on by vertebrate animals prior to the hydrogen bomb, the completely unexplained cutting off of all dinosaur lines in the Cretaceous is one of the most impressive cases of extinction that we know about. And when extinction happens to a vast, diverse and seemingly successful group like the dinosaurs, it demands an explanation. But though a great deal of thought has been given to the matter, it still remains largely an impressive mystery.

MANY theories have been advanced to account for the immense dying of the dinosaurs. Some of them are almost persuasive, some seem pretty desperate. Without going into the merits of these, it can be said that this great anomaly remains to confound them all: it was not a single species of animal that disappeared so unaccountably, it was several *orders* of reptiles. It was a broad spectrum of animal life occupying all sorts of environments and habitats. Some of the creatures were tiny, some gigantic, some ordinary reptiles, some among the most bizarre animals that ever lived. If too-great size, and thus too-great surface-to-volume ratio in times of rising temperatures killed off the sauropods, then what struck down the pterosaurs, most of which were wispy aerialists that lived in wholly different ways? If mammals ate up the eggs of the terrestrial dinosaurs, what plagued the live-bearing ichthyosaurs that ranged the open seas? And so it goes. The fact is, the event has not been accounted for. We



PHYTOSAUR



GAVIAL

There is an astonishingly close resemblance between the Triassic phytosaur, which became extinct 200 million years ago, and the gavial, a kind of crocodile found in Asia today. Both lived in swamps and on muddy riverbanks. Both were ferocious carnivores with long-toothed jaws for snatching fishes. But the phytosaur's nostrils were just in front of its eyes, while the gavial's are at the end of its snout.

PLACODUS

WALRUS

The eight-foot-long Placodus was also a Triassic reptile. Its stoutish body, short neck and tail and paddle-like limbs resembled those of the modern walrus, a mammal. Like the walrus, it was a marine animal that dived down to the bottom in search of shellfish which it crushed with its strong jaws and teeth. Although it lacked the canine tusks of the walrus, its front teeth were used as efficient cutters.

know only that a vast and far-flung fauna was wiped out and replaced by a fauna of mammals, leaving the world of today with only remnants of the once-great orders.

The dinosaurs were by no means the only Mesozoic reptiles that burgeoned and spread and then became extinct. Of the others, some made ventures into alleys that went quickly blind; others, like the ichthyosaurs and plesiosaurs were successful radiations that endured far longer than modern mammals have been on earth. Most of them were stocks that went back into the sea, and more will be said of them in the chapter on water reptiles. The grand days of the crocodilians were the Mesozoic days, when one kind reached a length of 50 feet; and crocodile architecture was paralleled in astonishing detail by that of the phytosaurs, a completely separate branch from the Permian reptile stem. The crocodiles continued; the phytosaurs, although in their own time they appeared to be just as promising, are gone, for reasons we do not know, and in all likelihood never will.

It pays a creature like man to keep in mind the vast time spans of the "unsuccessful" lives of these extinct groups. In evolution, of course, there is nothing novel about lines becoming extinct. Extinction is the rule, and survival the breathtakingly improbable exception. When you look about at the animals and plants on earth today, what you see are the favoured few. For every single stock running down into the present, thousands have been cut off. This applies not just to species, but to genera and families, and even to orders. During the Mesozoic, there were times when 16 orders of reptiles lived on earth at one time. Today there are four. One of these, the tuatara, is a single species with a drastically diminished range on a few New Zealand islands. Two of the orders are decadent, and only one, the Squamata, has shown recent evolutionary vigour. In brief, out of the whole teeming array of Mesozoic reptiles, only these stocks, listed here in the order of their branching out from the main reptile stem, remain on earth today:

(1) the mammals, which split off as the mammal-like reptiles in the Permian, some 250 million years ago;

(2) the turtles, which were probably derived during Permian times and were well developed by the Triassic;

(3) the crocodilians, which were derived from Triassic archosaurs;

(4) the tuatara, the only species of its order still alive, which has remained almost unchanged since its origin in Triassic eosuchian stock;

(5) the lizards and the snakes—the lizards having split off in the Upper Triassic, the snakes in the Cretaceous;

(6) the birds, which first appeared in the Jurassic in the intermediate form of *Archaeopteryx* and almost certainly were derived from Triassic archosaurs.

If we had been alive in the Age of Reptiles the great sight would have been the sweep of the deployment—the adaptive radiation of unprecedented types of life into unprecedented ways of living. Today, looking at what remains, we see the lesson of extinction and survival. The whole spirit of the grand, doomed days seems held in the small, cold body of the tuatara on the few chill islets of its dwindled range. Living on as unaccountably as the giants it once lived with died, it creeps out of its burrow in the evening, plods about in the mist to gather crickets to keep the old, small flame of its life alive; then, in the early morning, goes back again into the earth to which it has clung so stubbornly for some 200 million years.


Apodiformes
Streamertail
Passeriformes
Red Bird of Paradise
Psittaciformes
Gold and Blue Macaw
Coraciiformes
Lilac-breasted Roller
Coliiformes
White-headed Mousebird
Procellariiformes
Black-browed Albatross
Cuculiformes
Red-crested Touraco
The
27 Orders
of Birds
(One Representative from Each)
Caprimulgiformes
Pennant-winged Nightjar
Ciconiiformes
Glossy Ibis
Pelecaniformes
Brown Pelican
Falconiformes
White-headed Vulture
Gruiformes
Demoiselle Crane
Podicipediformes
Great Crested Grebe
Gaviiformes
Arctic Loon
Roger Tory Peterson

The 27 Orders

Every one of the 8,580 living species of birds has been assigned by ornithologists to one of 27 major groups or orders, although some experts put the number at 29, placing flamingos and touracos into orders of their own. Many of the birds in a single order may seem wildly unrelated, but they have skeletal or other features which, to trained scientific eyes, relate them unmistakably. The list below opens with the most primitive orders and ends with the most advanced. The figures for families and species are the latest available and conform to those in *The World of Birds* by James Fisher and Roger Tory Peterson (Doubleday, 1964). They show dramatically how poorly the more primitive orders are managing to survive compared to more highly evolved ones.

ORDER	LIVING FAMILIES	LIVING SPECIES
Sphenisciformes: penguins	1	15
Struthioniformes: ostriches	1	1
Casuariiformes: cassowaries, emus	2	4
Apterygiformes: kiwis	1	3
Rheiformes: rheas	1	2
Tinamiformes: tinamous	1	42
Gaviiformes: loons	1	4
Podicipediformes: grebes	1	17
Procellariiformes: albatrosses, fulmars, petrels	4	81
Pelecaniformes: tropic birds, pelicans, boobies, cormorants, anhingas, frigate birds	6	50
Ciconiiformes: herons, storks, flamingos, etc.	6	117
Anseriformes: screamers, swans, geese, ducks	2	149
Falconiformes: vultures, hawks, eagles, etc.	5	274
Galliformes: grouse, quails, turkeys, etc.	7	250
Gruiformes: cranes, rails, coots, bustards, etc.	12	185
Charadriiformes: jacanas, plovers, sandpipers, stilts, gulls, terns, auks, etc.	16	293
Columbiformes: sandgrouse, pigeons	2	301
Psittaciformes: parrots, parakeets, cockatoos, lories, lorikeets, macaws, lovebirds	1	317
Cuculiformes: touracos, cuckoos	2	143
Strigiformes: owls	2	132
Caprimulgiformes: frogmouths, nightjars	5	92
Apodiformes: swifts, hummingbirds	3	388
Coliiformes: mousebirds	1	6
Trogoniformes: trogons	1	35
Coraciiformes: kingfishers, todies, motmots, bee eaters, rollers, hoopoes, hornbills	10	192
Piciformes: barbets, honey guides, puffbirds, jacamars, toucans, woodpeckers	6	377
Passeriformes: flycatchers, larks, swallows, wrens, thrushes, warblers, sparrows, etc.	55	5,110
TOTALS	155	8,580

Red-footed Booby

One of the Pelecaniformes, an ancient order of fisheaters that includes the pelicans and cormorants, this bird nests on bushes and shows little fear of man. It has the long beak, large wings and short legs of the order, as well as webs between all four toes of each foot—the group's unique feature.

Mute Swan

Rearing in the water, a mute swan shows the pointed wing tips, dense plumage and broad, flat bill of the Anseriformes—the swans, geese, ducks and relatives. A wild European species brought to America as an ornamental park bird, it has spread widely in the northeastern states.

American Goshawk

This skillful predator, built for quick maneuvering, takes grouse and rabbits. Like most other Falconiformes—the hawks and eagles—it has strong wings, a hooked bill, sharp talons and keen eyesight. The carrion-eating vultures also belong to this order but lack the clutching talons.

Red Jungle Fowl

The progenitor of all domestic chickens, the red jungle fowl of Southeast Asia is grouped with such other fowl-like birds as grouse, pheasants and turkeys in the order of Galliformes. These are scratching birds, with strong feet and breast meat that is, as man well knows, white and succulent.

European Coot

A marsh bird, the European coot has lobed toes that work like rubber fins when it swims. Coots are related to cranes, rails and their allies, and classified as Gruiformes. This order shows wide diversity but has recently lost—and is losing—more species than any other major order.

Royal Tern

Erupting from a South Carolina colony, royal terns fill the sky with flailing wings. Terns are closely related to the gulls and black skimmers and belong with them to the order Charadriiformes, along with auks, puffins, skuas and a host of wading shore birds ranging from sandpipers and plovers to

stately avocets. Its members are found throughout the world, even including the arctic and the edge of Antarctica. The Charadriiformes are traditionally associated with the sea, beaches, marshes and salt meadows, but many of them are found inland, hundreds of miles from the ocean. Most of them are strong fliers, and some are the most remarkable migrators known. The golden plover, which is about the size of a robin and does not light on the water to rest, can nevertheless fly nonstop 2,400 miles from eastern Canada to South America and arrives with only a two-ounce weight loss.

Victoria Crowned Pigeon

One of the biggest pigeons, this 26-inch crested species belongs to the order Columbiformes, to which the extinct dodo also belonged. The Columbiformes drink by sucking up water, instead of tilting their heads back to swallow.

Rainbow Lorikeet

Brilliant plumage, a hooked beak and a distinctive toe arrangement—two in front and two in back—place the rainbow lorikeet among the ranks of such birds as parrots, macaws and budgerigars in the Psittaciformes.

Donaldson's Touraco

Though African touracos are classified with cuckoos as Cuculiformes, recent research suggests that they may be more related to the fowl-like birds. Some ornithologists would put them in a new order with the South American hoatzins, now in the Galliformes.

Hoopoe

A long-beaked male hoopoe brings a meal to its waiting family. Like such other Coraciiformes as kingfishers, hornbills and bee eaters, hoopoes nest in cavities. Possibly because of their foul nesting habits and the fact that a musty odor exudes from the female's preen gland, hoopoes, whose flesh is edible, are among the proscribed foods of the Old Testament.

Tawny Frogmouth

Nocturnal, as are most of the Caprimulgiformes, the tawny frogmouth has its own method of catching insects: eschewing flying prey it flutters down on creeping things. This order also contains the insect-catching potoos, nightjars, whippoorwills, nighthawks and the noninsectivorous oilbird.