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*Secretary of the
Smithsonian Institution*



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Wilson's phalarope (*Steganopus tricolor*), of America, a species in which the female (above) is larger and more brilliantly colored than the male (below)

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CLASS

WARM-BLOODED VERTEBRATES

PART I BIRDS

By

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PART II MAMMALS

By

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PART I

BIRDS

By

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Assistant Secretary, Smithsonian Institution

CHAPTER I

BIRDS IN RELATION TO MAN

WE have only to consider the great ostrich, with its two-toed feet and flightless wings, and the tiny humming birds (some of which are smaller than the larger insects), with bodies highly specialized for flight, to realize something of the complexity of that class of animals called birds. Yet in spite of the diversity indicated by these two extremes, the various birds betray remarkable uniformity in their structure and have many characters in common. They all have, for example, a body covering of feathers, a characteristic which instantly differentiates them from all other vertebrated animals. Though feathers may vary from soft, fluffy downs and graceful plumes to stiffened quills that give to wings the supporting surface essential to flight, yet as a body covering they are so characteristic that we can always identify them and so assign the most peculiar of birds to its proper class. For practical purposes, therefore, it is sufficient to define birds as warm-blooded animals with a body covering of feathers.

Birds as a group have attained almost universal distribution over the earth, thanks to their ability to fly and to their many specializations of form, which permit them to maintain a continuous existence over or on both land and water. As a result of these adaptations to varied environment some type of bird may be found at some season of the year everywhere in the world, with the possible exception of the central part of the vast Antarctic continent, which is not yet thoroughly explored. Even the broad areas of ocean furnish a home to peculiar avian species at

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certain seasons. Some sections of the open seas may be birdless for months at a time when the species that frequent them seek the land to breed; but at the close of their reproductive season the birds come again to these apparently trackless wastes of water, either as travelers migrating over them or, if conditions are suitable for their existence, as sojourners. The seas and lands of the Arctic regions are as friendly to species of birds adapted to them as one noted explorer has observed they may be to man under suitable circumstances. Land birds, like the raven and snow bunting, nest far to the north on the coasts of Greenland, and in summer gulls and other aquatic species traverse the vast spaces of the north polar sea. Deserts as well have their feathered inhabitants.

As individuals birds may abound in many temperate regions, but it is within the Tropics that the greatest variety of species or forms occurs. And, as might be expected, where the topography of the land varies extensively within a comparatively small number of miles from mountain highland to humid, tropical lowland, there we find the greatest concentration of species. The record for such concentration for a limited area is held at present by the Republic of Ecuador: there, according to Dr. Frank M. Chapman, within an area of approximately seventy-five thousand square miles, 1,508 distinct avian forms are at present known, and the list is not yet complete. To understand what these figures signify, contrast them with the list of known forms for the State of California, which has twice the land area and a highly varied topography and environment but which, according to the latest figures (March, 1925) of Dr. Joseph Grinnell, supports only 594 forms of birds. The influence of the Tropics on bird life is indeed favorable.

As to the relation of birds to mankind, we may be sure that well back in the prehistoric past they began to play an important role in human economy. The domestication of the barnyard fowl, goose, duck, and pigeon is

PLATE I

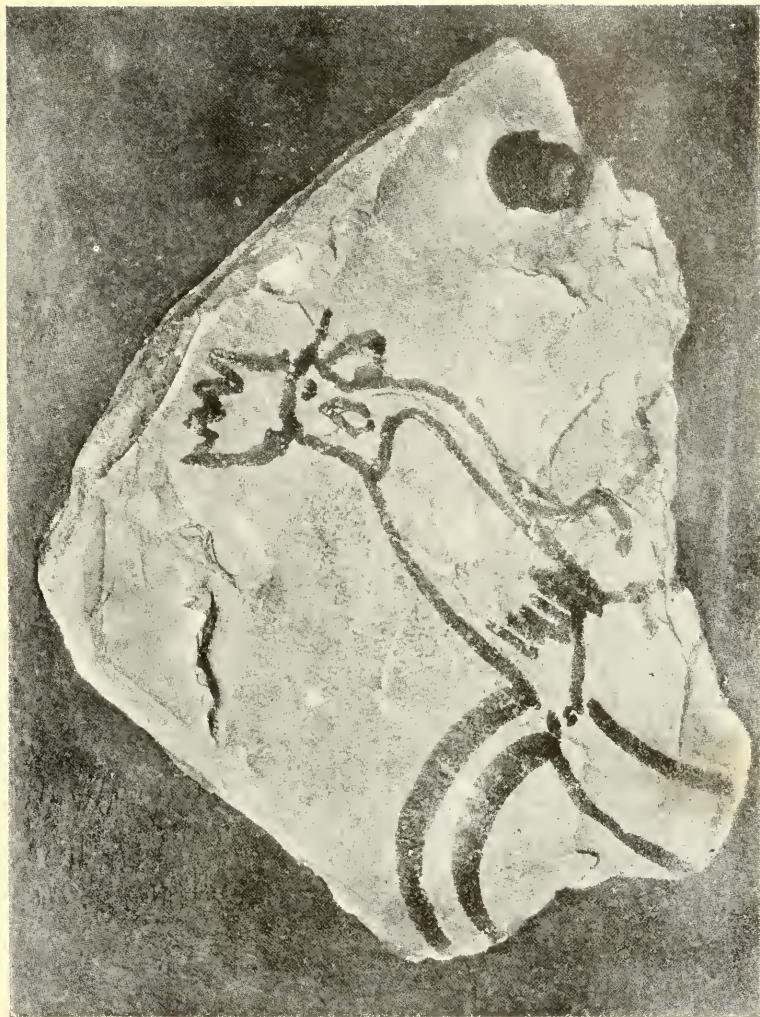


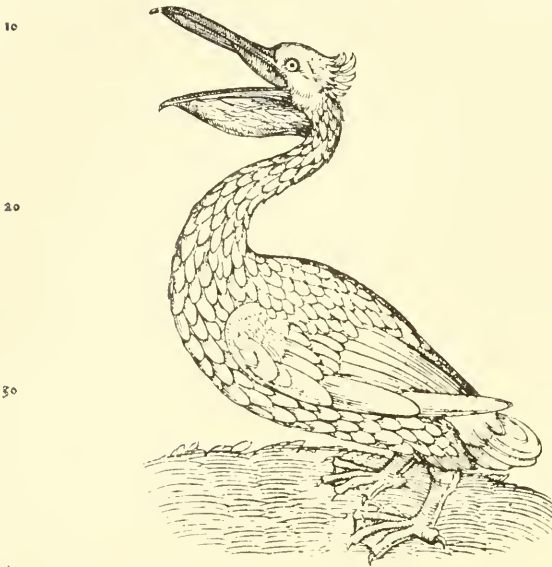
Figure of domestic cock painted on flake of stone about 1400 B. C. From tomb of Tut-ankh-Amen. After P. R. Lowe

De Onocrotalo. A. Lib. III. 605

fuscus, pars supina alba, maculis aliquot asperfa cinereis. partem etiam sub cauda albere puto. longiores alarum pennæ nigricant. rostrum longiusculum modicè inflectitur. Sed cum de occultatione eius nihil cognorim, ænanthen esse non affero. Speciem eius in præcedente pagina adiecimus.

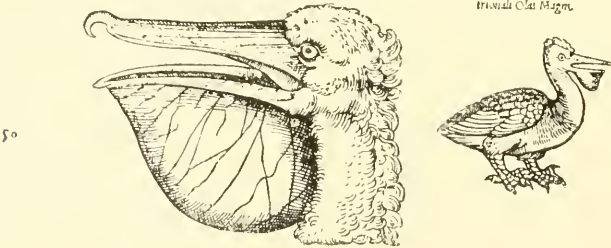
DE ONOCROTALO.

Icon hæc onocrotali est, capti in Helvetiâ in Litu prope Tugium, quem ipsi viderunt.



Onocrotali caput, à pictore quodam olim nobis communiatum.

Onocrotali figure ex tabula Septentrionali Clai Magnæ.



A.

40 **M**A NC AUEM à Latinis truonem appellari Verrius Flaccus scripsit; unde Cæcilius Comicus (ut citat Festus) irridens quendam ob nali magnitudinem dixerit: Proh dii immortales, unde hic præcepit truon: Kaath Hebraicam uocè, קאט, interpretantur alij cuculum, alij onocrotalum, peiecanum, mergulum, upupam; ut diximus supra in historia Mergi in Ec 3

BIRDS IN RELATION TO MAN

hidden in antiquity. The fowl may have been domesticated in Burma or India, as these countries are within the range of its wild form, and the Chinese have a tradition that the fowl came to them from Burma about 1400 B.C. The Code of Manu, most authoritative of Hindu law books, whose origin has been placed at varying dates between 1200 B.C. and 200 A.D., forbids the eating of the tame fowl though it permits the eating of the wild form. Aristophanes calls the fowl the "Persian bird," indicating that it came to Greece from Persia (Plate 1). According to Canon Tristram, an English writer of the last century, knowledge of the domestic pigeon in Egypt goes back to the fifth dynasty, about 3000 B.C.; while existing records of a date only shortly later indicate the use of pigeons as message carriers between distant points.

The earliest human records relating to birds go back to the period following the Ice Age, when that branch of the prehistoric human family known as Aurignacian man lived in what is now France and Spain. This primitive people painted or engraved animal figures, including those of birds, on the walls of caves and carved them on bits of horn, bone, or stone. The birds represented in that remote human art which have been identified so far include among others the crane, duck, goose, grouse, owl, partridge, and swan. The drawings date back many, many thousands of years. We find representations of birds in

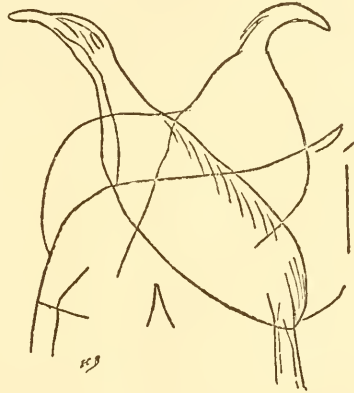


FIG. 1. Figures of birds, probably bustards, traced in the early post-glacial period (Aurignacian or Solutrean) on the walls of the cave of El Pendo, northern Spain. After del Rio, Breuil, and Sierra

BIRDS

Paleolithic cultures later than the Aurignacian (Fig. 2), but not until Neolithic times, long after the close of the Ice Age, do they become at all common. In the cavern at Tajo Segura, in Spain, Colonel Willoughby Verner has found figures of the great bustard, crane, duck, goose, raven, spoonbill, flamingo, purple gallinule, glossy ibis, stork, eagle, and marsh hawk. These indicate consider-



FIG. 2. Bird carved from stag horn, from post-glacial deposits (Magdalenian) of Andernach, Germany. After R. R. Schmidt

able familiarity with bird life on the part of a people that lived, according to the present estimates of archeologists, from six thousand to eight thousand years ago. It is probable that most of the species included furnished food for these ancient people.

In any Indian village in the wilder parts of South America today the traveler may see birds of various kinds which have been taken captive while young and which, through chance or choice on the part of their captors, have escaped being killed for food. We may fairly assume a comparable phenomenon to have been the first step in the domestication of our various domestic birds. As aesthetic sensibilities awakened in the developing brain of man he began to keep birds captive for their beauty, oddity, or pleasant song, a custom which has grown in our day to a point where it has assumed some importance in trade.

Ctesias, a Greek author, writing before 400 B.C., mentions parrots as birds that speak the language of man—a fact which indicates that parrots were then kept captive, since they must have been brought from a distance, probably from Africa, and since they develop an imitative habit only in captivity. The Romans, at a little later

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period, are said to have confined parrots in silver-wired cages with frames of tortoise shell and ivory. The common canary was known in a domesticated state as early as the close of the fourteenth century but seems to have been rare as late as the year 1555, if we may judge from a statement of Conrad Gesner, who was deeply interested in birds of all kinds (Plate 2), to the effect that he had heard of these birds but had never seen one. The original canary stock is reputed to have come from the Canary Islands, where the wild form (*Serinus serinus canarius*) still is common. The wild form has mixed gray, olive-green, and yellowish plumage, the sides and flanks being streaked with a dusky shade—a pattern at times reproduced wholly or in part in domestic birds—but by the close of the seventeenth century pure-yellow and pure-white canaries were known.

Another group of birds that came early into semi-domestication were hawks and falcons, which were trained for hunting. The earliest references to the domestication of falcons for hunting winged and four-footed game are Chinese, but of indefinite date. The use of falcons in hunting is recorded from Persia as early as 1700 B.C. and is believed to have existed in Europe in 300 B.C. Hunters went afield carrying on their wrists these fierce birds, with eyes hooded, tethered by a short leash. When game was sighted the hawks were released in its pursuit. The birds were trained to return to their masters at the sound of a whistle. For a long period, until, in fact, gunpowder and firearms came into general use, falconry remained the accepted method for hunting small game, and there are extended references in literature to the sport. In some sections of central Asia today golden eagles are trained to hunt gazelles and other game.

The study of birds as a branch of natural history, that is, the science of ornithology, follows two general methods: First, observation of the living individual and its reactions to the varying conditions that it encounters;

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second, examination of the dead body. Observations of the living bird enjoy the greater popular interest and have the larger following, particularly among those for whom ornithology is an avocation. Birds are easily observed, both because they are the most conspicuous of vertebrate animals in a wild state and because they abound nearly everywhere. In addition, when given the slightest encouragement they come readily about our homes, unless these happen to be in such unfavorable locations as the centers of great cities.

Primitive peoples everywhere have noted the movements of birds as portents of the weather and of seasonal or other natural phenomena. I have had hunters among the Toba Indians in the Pilcomayo jungles of northern Argentina recount at my camp fire as part of the news of the day the sighting of rheas (flightless running birds remotely related to the ostrich) on certain open plains and of wild ducks or screamers on the lagoons, or the finding of the nest of the *yacu*, a pheasantlike bird that lives in trees. The passage of migratory birds figured frequently in the omens by which the priests of ancient Greece and Rome attempted to forecast future events. From unrecorded times men have used the flights of migratory birds as omens; savage peoples have named calendar periods for migrants that appeared regularly in the course of the seasons; and the migrant flights of ducks and geese still supply the countryman with important news.

The study of dead birds is likewise nothing new, since it began in a primitive way with the first preparation, in any manner, of the bodies of birds for human food and the utilization of feathers and skins for ornament or dress, of tendons for sewing, or of bones for tools. Though modern studies of the dead bird include dissections of specimens preserved in alcohol or other fluid and the examination of skeletons, the majority of ornithologists working in museums devote their attention to specimens prepared in a

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special manner. This special preparation consists of skinning the bird in such a way that the feathers, bill, and feet are kept intact, after which the skin is filled with cotton, tow, or excelsior and arranged in compact form to appear like a complete bird. Such specimens, known as study skins (Plate 3), are readily prepared by expert naturalists during their travels; and in the museum they require little space, as they rest in sliding trays in specially built cabinets provided with tight-fitting doors to prevent the entrance of skin-destroying insects. Examples of interesting species are mounted for public exhibit, but these are only a small proportion of the great collections of bird specimens possessed by the larger museums, since to exhibit too many would only confuse the public.

It may appear on casual inspection that our study collections include too many duplicates—too many specimens of the same species of bird. But only by extensive sets of specimens can we learn the differences in color or size, great or small, that may exist in male, female, and young at different seasons of the year or in different parts of the geographic range, the manner of molt and feather renewal, and many other items of value and interest. In some cases fifty or more individuals of one kind of bird may be needed to exhibit properly these and other points. Furthermore, the ardent conservationist need feel no alarm at the size of the bird collections in our larger museums. In many of our States a sportsman is permitted by law to kill fifteen ducks in any day of the open season, which means that the number of ducks shot for sport each year throughout our country runs literally into millions. Compare these numbers with the series of twenty-five or, rarely, fifty skins of a species found in each of a few museums and it will be seen that the individuals preserved for science amount to practically nothing in the annual slaughter. The great majority of small birds, of course, are not hunted as game and so escape the sportsman. The comparatively few killed annually for science

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have small bearing on the continuance of most species, though certain forms of very restricted range and others, like the whooping crane and ivory-billed woodpecker, which are near extinction, need careful protection if they are to endure.

It is also worthy of mention that hundreds of birds killed by accident come to museum collections for preservation as specimens. The National Museum constantly receives bodies of birds which have met their death by striking against wires while in flight or which have been killed by cats, automobiles, or other agencies. A male flicker is killed in fight with a rival and is brought in for the collection by a museum messenger who chances to witness the battle; a guard on night duty at the Washington Monument brings in a dozen migrant warblers that have met death by striking the great shaft of stone during the hours of darkness. Lighthouses have sent in hundreds of specimens accidentally killed, and on one occasion the National Museum received nearly one hundred birds killed by flying against the Statue of Liberty in New York harbor. It has been my good fortune to preserve for scientific study many hundreds of ducks and other water birds which had succumbed to alkali poisoning in the vicinity of lakes in the Great Basin region, and to secure dozens of valuable specimens from dead birds washed up on sea beaches in various parts of the world.

As a final comment on this matter I may add that the first collections made for what is now the United States National Museum were secured about ninety years ago, while a few specimens in its cases date back to the year 1817. In other words its collections have been accumulating during more than a century, a sufficient length of time to assure any one that the number taken has not threatened the existence of any species of bird.

The art of preserving the bodies of birds more or less permanently is older than history; probably it began with the preservation of such single feathers, partial or entire



Study skins as used in scientific researches. Specimens from Haiti

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skins with the feathers attached, and dried or smoked heads and feet as we find used for ornaments by primitive peoples of today. The mummification of birds was practiced in Egypt in the fourth century B.C. and furnishes us with the earliest known instances of their preservation. The mummies, which include kites, eagles, falcons, ibises, and numerous other birds, were entombed with human bodies; and so well have they endured that we can still identify them by their bones and feathers. Thirty-five species or more have been recognized in these mummies.

Aristotle, the father of recorded natural history, living from 385 to 322 B.C., is said to have had at his disposal, thanks to the patronage of Alexander the Great, several thousand persons who hunted and fished and otherwise gathered information for his work on the natural history of animals. He mentions many birds and must have had at least partial specimens of some of them, though of this there is no actual statement. To reach authentic records of the possession of preserved specimens we have to skip many hundreds of years. Between 1415 and 1440, Nicolo di Conti secured in Java preserved skins of birds of paradise, which came as articles of trade from New Guinea and the near-by islands. These were prepared by natives and were the forerunners of the bird skins prepared for scientific study today.

Early naturalists in their travels depended largely on sketches or descriptions for information about strange birds. William Turner, writing in 1544, asked his readers to send him notes on any birds they might secure that were not already described in his published work. But actual specimens were also used, and we know that birds or fragments of birds were brought back to Europe about this time from the New World. Pierre Belon in 1555 mentions dried skins of birds brought by mariners for sale, describing from this source what he called the "merle de brésil," which is a species of tanager (*Ramphocelus*

BIRDS

brasilius) of bright plumage. He outlines methods of preserving birds by removing the intestines, placing salt in the body cavity and throat, and hanging the body up by the legs to dry; or by removing the entire skin and preserving it in salt. John Tradescant writes, during a voyage to Archangel in 1618, that "on Monday the 13 of July there wer many small bird come aboard the shepe being sume 3 leags from the shore. I have thre of ther skins whiche wer caut by myself and the rest of the company." James Petiver, a London apothecary, in 1698 instructs us that "smaller birds are easily preserved Entire, by opening their Bodies which is best done by cutting them under the Wing, and take out their Entrals, and then stuff them with Ockam or Tow mixt with Pitch or Tar." Birds were also preserved entire in spirits by numerous travelers. After the middle of the eighteenth century, however, naturalists began to make study skins, and by the first of the nineteenth century this had become the standard method and has led to the accumulation of our present-day collections.

Among the oldest bird skins of which the approximate age is known are those found in a curious book preserved in the Emma Shearer Wood Library of Ornithology at McGill University in Montreal. This book contains illustrations made by cutting off the skin of one side of a bird and pasting it on the page in lifelike attitude, with long feathers arranged to indicate the wing, and the bill and feet glued in place. The considerable number of species thus illustrated includes an American parrot. According to the title-page this work was prepared in 1618 by Dionisio Minaggio, an official of the court at Milan. The museum at Upsala, Sweden, is said to possess half a dozen bird skins known to have been in existence in 1747, while the University of Parma has a few specimens hermetically sealed in glass bottles by Jean Fourcault, who died in 1775. Finally, in the museum at the University of Oxford there are the head and foot of a dodo which John

BIRDS IN RELATION TO MAN

Tradescant preserved in 1656 and which came to Oxford from Sir Elias Ashmole in 1669. The head of another dodo, a species which was last recorded alive in 1681, is also preserved at Copenhagen. In addition to these early-preserved specimens we still have the Egyptian mummies already mentioned and feathers found in ancient Indian dwellings in America. Ravages of feather-eating insects have, however, destroyed the greater part of the earlier specimens, a destruction that began to be checked successfully only about 1740 with the employment of arsenic to poison the skins. Today we must look to museum collections to examine the great auk, the passenger pigeon, the Labrador duck, and scores of other birds that man has exterminated. Meanwhile the extension of human civilization to the remotest sections of the globe tends yearly to crowd out of existence thousands upon thousands of other species. Only a relatively small number of birds find the new physical environment created by man favorable to their continuance. The rest succumb, and the next fifty years are sure to witness a tremendous diminution in the number of birds and other wild creatures. For this reason museum collections increase in importance yearly, and we need to take care that specimens of birds threatened with extinction are preserved.

In concluding this chapter it may be said that the museum investigator, absorbed in his trays of skins or bones or in his jars of alcoholic specimens, and the observer watching living birds in the open air are working toward a common end. Each is dependent on the other, and the work of both is necessary to complete our knowledge. The manuals on which the observer depends to identify species come almost entirely from the indoor scientist, as does our knowledge of the limits of families and their relationships, of ancestry through fossil records, and of the physical composition of their feathers and bodies. The outdoor observer contributes to our knowledge of the psychology, manner of life, nesting, and haunts

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of birds, and furnishes the laboratory student with specimens. A modern development that in a way combines the methods of the two schools is the use of living birds in controlled captivity for the study of various phases of their reactions to environment, their development, and their psychology.

CHAPTER II

ADAPTATIONS FOR PROGRESSION BY FLYING

FLIGHT has been a powerful factor in controlling the bodily form of birds, maintaining it within the boundaries of a very definite pattern, and allowing only such variation as does not interfere with a flying existence. It is true that a number of species of living birds, like the ostriches, penguins, and numerous rails, as well as various peculiar fossil forms (see Plates 17 and 19), do not, or did not, fly. Some authorities have gone so far as to argue that the ostriches and penguins have always been flightless, and that they have not descended from the same ancestor as have the flying birds. I hold, however, with many others, that the form of the wing in ostriches and penguins, with the fused bones of the hand and other peculiarities, indicates definitely that these groups have come from flying ancestors and have lost the power of flight as they became specialized for their own peculiar habits of life. No definite basis seems to exist for the suggestion that birds have originated from two distinct and separate lines of ancestors.

The adaptations of birds for flight, though presenting a number of departures from those found in other flying animals, are relatively simple. We find the most striking modification in the forelimb, which has become a wing with feathers projecting from its posterior margin. The wings form a strong supporting plane which maintains the bird in the air, provided it has a certain forward momentum, and at the same time can be flexed easily. Thus as

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the wings are moved up and down the form of the surface changes first to provide the power for driving the entire body forward and then to return with the least amount of retarding friction to position for another driving stroke. The wing performs the functions of the plane in the aircraft and is far more efficient because it is in three separate sections—the humeral part, corresponding to our upper arm, the forearm, and the hand. This makes it possible for the bird to adjust its wings readily to changing stresses and conditions, and when it alights to fold them instantly to fit the curves of the body and thus permit freedom of movement. (For illustrations of the form of the wing in living birds, see Plates 4, 5, and 6.)

The bones of the hand in the bird's wing, which bear much of the stress of flight, are stiffened and fused so that they do not have the pliability found, for example, in the hands of lizards and squirrels, which are used for grasping. To hold or draw objects to itself, the bird must employ the foot assisted by the bill or, as do the sparrows, must depend upon the bill entirely for that purpose. The stiffened hand, however, forms a perfect support for the outer feathers of the wing, which are of prime importance in flight.

The driving force in avian flight is the muscles of the breast, which in flying birds are developed to great size; they are attached to a broad breastbone which has a high central keel. Long tendons transmit the driving power to the wing bones. The muscles found on the wing itself are small, their purpose being to hold the wing rigid when it is extended, to control change in the shape of the wing during flight, and to hold the wing securely against the body when it is folded. The bulking of the flight muscles on the lower surface of the body results in a low center of gravity, which is advantageous in affording stability during flight.

Two adaptations reinforce the skeleton of flying birds: Thin, narrow plates of bone, called the uncinatè processes,



Herring gull (*Larus argentatus smithsonianus*), illustrating the form of the wing and the overlapping arrangement of the wing feathers. Photograph by Dr. Frank N. Wilson



Upland plover (*Bartramia longicauda*), a member of the sandpiper family that nests in eastern North America and winters in Argentina.
Photograph by Dr. Frank N. Wilson

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extend across the ribs, and the shoulder blade extends along the sides of the back. Together these bones add to the rigidity of the bird's body necessary during the tremendous exertion of flight.

Feathers constitute the most novel of the adaptations that make bird flight possible. Whether feathers originated in response to the need of a covering for the entire body, or as specialized structures on the limbs, is an abstruse and debatable point which we may disregard. The important point is that the long feathers of the wings, with those of the tail, form a supporting plane of sufficient extent and strength but minimum weight which is at the same time flexible for such instant adjustments as may be required. Flying insects and flying mammals, like the bats, utilize continuous membranes as supporting surfaces. Insects have a double wing, though the flies (Diptera) are so expert in balancing that they employ only a single wing on each side, the second being reduced to a mere vestige. In contrast to the continuous membrane of which the wings of insects are composed, the overlapping feathers which make up the wings of birds can be separated at the tips at will and so permit adjustment to pressures by letting air slip through—an adaptation that must be highly advantageous (Plates 4, 5, and 6). Taken as a group, birds are unquestionably the most efficient flying creatures in existence.

We do not ordinarily pause to remember, in looking at birds, that it is their feathers alone that we see; but one has only to visualize a plucked chicken in the market to realize this fact and the importance of feathers to a bird's appearance.

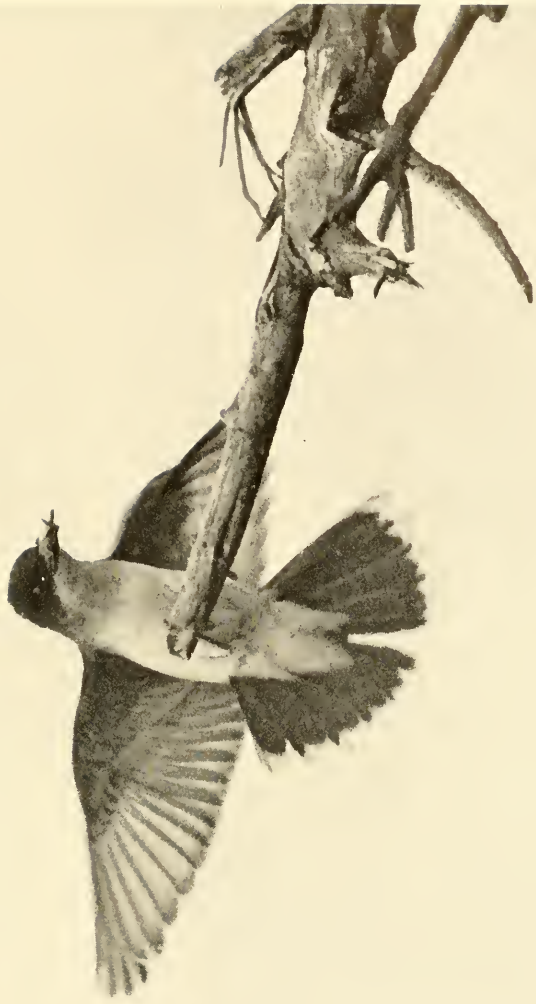
Whether a single feather, regarded superficially, attracts us or not, when examined closely it always proves to be of striking beauty and very complicated in form (Plates 7 and 8). The feather grows as a single shaft, which is usually hollow at the base but solid toward the tip (Plate 7, left). This shaft is generally slightly curved

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to allow close adjustment to the adjacent feathers. The end of the quill, though embedded to a greater or less extent in the skin and firmly fixed, can nevertheless be moved by the contraction of delicate muscles that underlie the skin. This happens when a bird "fluffs" its feathers. The embedded end of the quill has a small opening, of no importance in the full-grown feather, but which gives entrance during the growing period to materials from which the feather is formed. Very often an aftershaft accompanies the shaft on the lower side. In appearance this resembles a small duplicate feather which springs from the upper end of the quill. Most birds have it, but ostriches, rheas, pigeons, cuckoos, and many others do not. The aftershaft reaches its maximum size in the cassowaries and emus, in which it is as large as the main shaft. Though the aftershaft may appear to be a miniature of the main feather, it does not possess a firm web and seemingly serves merely to fill in space at the base of the main feather.

Woodpeckers, which use the tail as a brace in climbing, have the free end of the shaft of the tail feathers stiff and firm to give them supporting power (see Plate 12). In the chimney swift the shaft projects beyond the web as a pointed, black needle which serves a similar purpose when the bird clings to the inside of chimneys or of hollow trees.

The main part of the feather, the web, is composed primarily of filaments known as barbs (Plate 7, right, and Plate 8, left), which grow out like little branches parallel to one another and very close together on either side of the shaft. These barbs are clearly visible to the eye as component parts of the web. Occasionally they are simple and straight, as in the ornamental plumes of the bird of paradise or egret, in which the soft appearance of the plume results from this disjointed construction. In the ordinary run of feathers, however, we find that the barbs, while yielding to the touch, cling closely together, and that they are slender filaments with a horny rib or stem from which



Kingbird (*Tyrannus tyrannus*), illustrating a type of short, rather broad wing with pointed tip. Photograph by Dr. Frank N. Wilson



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tiny branchlets—barbules—project on either side (Plate 8, left). Each barb, therefore, represents a tiny replica of the main feather. From the sides of some of the barbules there project still smaller filaments known as barbicels, which often terminate in little hooks called hamuli. These attach themselves to the adjacent barbules (Plate 8, right), and the whole forms a structure which, though slight of form and light in weight, is highly flexible and pliant.

Barbs, barbules, and barbicels are tiny. Gadow records that in the wing feather (primary) of a crane he found 650 barbs composing the inner web. Each barb bore about 600 pairs of barbules, making approximately 780,000 barbules for the inner web alone, and more than 1,000,000 for the entire feather. Beebe has estimated the number of barbules in the six-inch wing feather of a pigeon at 990,000. Since these figures take no account of the still finer divisions known as barbicels, we may well be astounded at the enormous complexity of a feather, especially when we consider the great number of individual feathers required for the body covering of a single bird. R. C. McGregor has patiently counted the individual feathers on a Savannah sparrow to find that they number 1,899; on a glaucous gull, a species of large size, he counted 6,544. The number of smaller filaments in such a mass of plumes surpasses the comprehension of the human mind.

The feathers on a bird's body are of different kinds. The conspicuous ones, such as compose the wing and tail plumage, bear the name "contour feathers." They are well formed, with strong shaft and broad web. Modified contour feathers are seen in the long bristles, known as rictal bristles, which grow about the mouths of birds like the whippoorwills and redstarts, whose habit it is to capture flying insects on the wing. The "eyelashes," long hairlike filaments that surround the eyelids of hornbills, are other modifications of the same type of feathers.

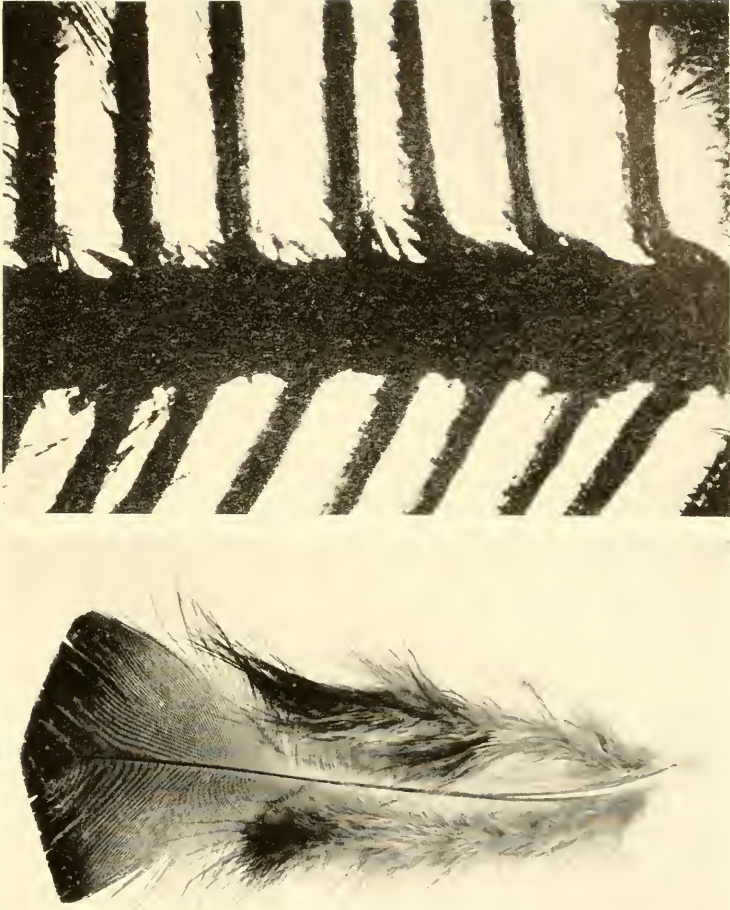
The soft, fluffy growths usually found about the bases

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of contour feathers are the down feathers. They have a well-developed quill (the end embedded in the skin) but a weak shaft (the projecting end) which bears a soft, spreading web, lacking entirely the coherence and firmness of the contour feathers. Down feathers are especially abundant in ducks and in birds of prey and have a distinct function in maintaining body warmth, growing heavier and denser in cold weather than in warm. Usually down feathers are completely concealed in adult birds, but in Old World vultures they may cover part or all of the head and neck. Many young birds, like chicks, ducklings and baby owls, have down feathers of a slightly different texture than those of the adult and which may cover the entire body,

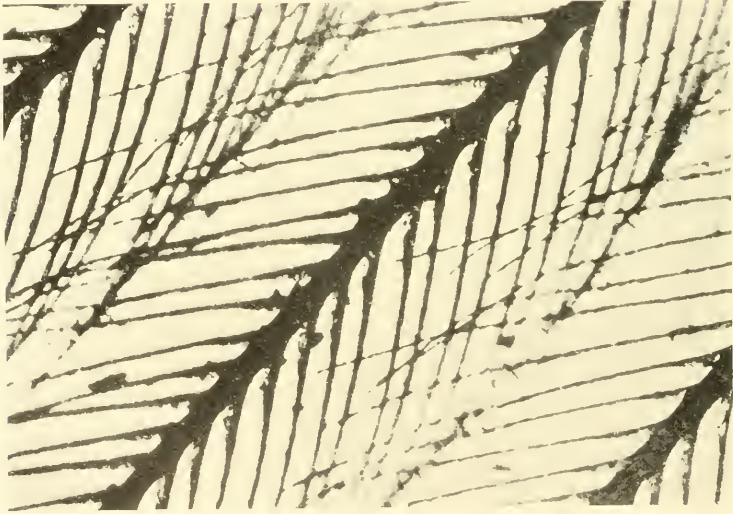
Hairlike filaments known as filoplumes are scattered over the bodies of some birds. These may be as long or longer than the adjacent feathers and are the "hairs" seen on the bodies of full-grown chickens when plucked. Filoplumes are supposed to be degenerate contour feathers of which only the shaft, with perhaps a few lateral filaments, remains. Usually we find them arranged on either side of contour feathers. We do not know their use but possibly they are remnants of some primitive type of feather covering.

Powder downs, restricted to a limited number of living species of birds, are the most peculiar of feather structures. In these the shaft has an opening at the projecting end, and about it grow feathery filaments. Usually powder downs are massed in distinct patches on the sides of the breast and the lower back, but in a few birds they are scattered singly, at random, among the contour feathers. Where they grow in patches they form thickened, easily detected areas in the skin. Powder downs are so named because the cellular sheaths covering their barbs disintegrate into a fine powder as the barbs grow. This powder, gray or white, is produced in considerable amount, since, unlike other feathers, which to all intents and purposes become dead structures when they attain a maxi-



The structure of feathers: Left, contour feather of wild turkey; right, portion of shaft with barbs from contour feather of house martin, enlarged 40 times. After J. S. Gladstone

PLATE 8



The structure of feathers: Left, barbs and barbules in contour feather of canary, enlarged 130 times; right, barbicles and hamuli of golden eagle, enlarged 500 times. After J. S. Gladstone

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mum size, the powder-down feather continues to grow as long as the bird lives. The powder produced is not oily as is usually supposed, its smooth feeling when rubbed between the fingers being due to the microscopic size of the flexible plates of horny material that compose it.

The use of these curious powder downs has aroused considerable discussion. Many have believed that in herons at least they are luminous and attract fishes at night, but there is no basis for such a belief. The truth is that the powder downs are used to dress the feathers, in the same manner as is the oily secretion produced by the oil gland at the base of the tail. I have observed in young captive herons that the powder downs developed simultaneously with other body feathers, while the oil gland did not become functional in producing its oily fluid until the bird had reached a later stage of growth. When young herons kept in captivity preened their feathers they rubbed the bill repeatedly in the extensive powder-down patches on either side of the breast until they had gathered a small amount of the powder on the tips of the mandibles, and then they pulled body and wing feathers quickly through the bill to distribute this substance over the surface of the quills, where it evidently served as a dressing.

In some parrots powder downs occur singly, scattered at random over the body. These birds distribute the powder among the plumes by fluffing the feathers and then shaking them quickly. At times, with such quick movement, small amounts of the powdery substance rise in the air about the bird like fine, barely perceptible dust.

A striking peculiarity of powder downs lies in the fact that though found in only a small number of species, these are scattered through the bird kingdom apparently at random. For example, powder downs occur in all the herons, in the marsh hawk and many other hawks, and in some parrots, but in the great group of perching birds, only the wood swallows (*Artamidae*), found in Australia and the Orient, have them.

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Unlike chicks and ducklings, whose bodies are completely covered with down when they emerge from the egg, the young of many of our common birds (like the warblers, sparrows, flycatchers, and thrushes, which remain helpless in their nests for some time after hatching) have only little tufts of hairlike down scattered scantily over the head and body. Such tufts are wholly insufficient to aid in keeping them warm. A few, like the blue jay, loggerhead shrike, frigate bird, and pelican, are naked when first hatched from the egg but develop complete or partial coverings of down later. The nakedness of these young when born into the world represents an extreme in specialization.

Though superficially the body of the adult bird seems uniformly covered with feathers, closer examination reveals that feathers grow in definite tracts of the skin and that the intervening spaces are bare (Fig. 3). In young chickens in which the growth of the body has outstripped the growth of its feather covering, the feather tracts and bare spaces show clearly. The arrangement of the feather tracts in most birds follows the same general pattern: The head has a rather even covering of feathers; a tract runs down the back, enlarging in its central section; another follows each side of the breast; and the wings and the upper parts of the legs, as well as the tail, have each its own tract. Many specialized birds exhibit variations from this general pattern, the bare head of birds like the turkey buzzard exhibiting one of the most obvious.

Feathers grow from a little point sunk in a tubelike pit known as the feather follicle. From this point an elongated papillus develops and pushes rapidly out as a pin-feather, which soon bursts its sheath to spread out in the familiar structure of the feather. When fully developed, growth ceases and the feather receives no further nourishment from the body of the bird. It is then a dead structure, like the free end of a finger nail, and may be cut without sensation on the part of the bird. The feather is

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delicate enough to be subject to wear and must be renewed at regular intervals, usually once each year when the bird molts. In molt the worn feathers become loosened in their sheaths and drop out, and a new feather germ, which has been forming in the feather follicle at the

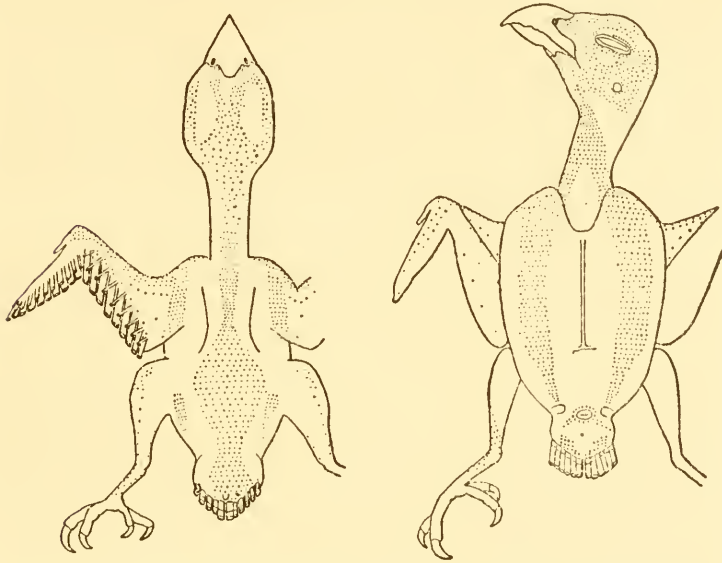


FIG. 3. The arrangement of the feather tracts in the gartered trogon (*Chrysotrogon caligatus*). Drawn by Alexander Wetmore

base of or beside the old feather, develops into a new structure in exact imitation of the original growth. This annual shedding usually follows the breeding season. At this time adult birds, in very worn dress, become dull and quiet, cease singing, and retreat to sheltered places where they are not easily seen. Young may be molting at the same time; in most birds the first plumage grown by the young during the early weeks of life is evanescent, and gives way almost immediately after growth to an adult dress, usually of a different color from the nestling dress.

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In the ordinary form of molt, feathers fall a few at a time and new ones begin immediately to appear in their places. As these new feathers grow, other old plumes fall and are in turn renewed. Thus the molt continues from four to six or more weeks, during which the bird may present an extremely ragged appearance, though at no time is its body predominantly bare. The wing illustrates effectively this regular sequence of shedding and regrowth, there being at no time any large gap in the feathers, so that the ability to fly is maintained throughout the entire molting period—a matter of great importance to a creature largely dependent upon its wings for transportation and for escape from its enemies.

Ducks and geese, however, as well as rails, flamingos, and grebes, have an entirely different wing molt from that just described. In these birds all the wing quills, with even the smaller feathers known as wing coverts, fall at practically the same time, so that the wing is almost bare, leaving the bird for a month or more entirely flightless (Plate 9). During this period, ducks, geese, grebes, and rails resort for safety to marshes, where they hide in rushes or other dense growth; in the northern tundras, where many ducks and geese breed, they retreat to small open ponds or lakes where they may hope to remain unnoticed. In this flightless state these birds are known as "flappers," a word that describes their condition accurately, since when alarmed they dash off across the water with rapidly beating wings, traveling so fast that they are usually hidden in the rushes before one realizes their true condition. Molting takes place in ducks and geese from July to September, during which flappers are only rarely seen. After five weeks or so of seclusion they appear once more in the open. In Canada geese the wing molt in the parents comes soon after the young hatch, so that both young and old mature their wing feathers and gain the power of flight at the same time in late summer.

The progress of the molt in each species of bird follows

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a definite, regular course from which normally there is little variation. Many birds have a complete molt at the close of the breeding season. A few, like the swallows and some birds of prey, have the annual molt during winter. Some sandpipers and plovers molt from a breeding plumage into a fall or winter dress, and then sometime during the winter change again into another breeding plumage. Summer and winter plumages may be alike, as in the swallows, or entirely different, as in the male scarlet tanager, which exchanges its brilliant red breeding dress for olive-green in winter, though wings and tail remain uniformly black throughout the year.

The ducks of the Northern Hemisphere also exhibit a peculiarity in color variation. Most male ducks wear a bright-colored breeding dress, well exemplified in the brilliant-green head and chestnut-brown breast of the male mallard. In June, at the close of the breeding season, these males molt and assume a dull plumage called the "eclipse plumage," very similar to that of the female, and which they retain during the period of wing molt. In the fall most species replace the dull plumage with the bright-colored dress that is carried into the next breeding season. The ruddy duck and the blue-winged teal, however, carry the eclipse dress longer. Some have considered this dull plumage a wise provision of nature to protect the male during the flightless period, while others have believed it merely a repetition of an early type of plumage. Curiously, eclipse plumage is not known in the ducks of the Southern Hemisphere.

Under unusual circumstances the eclipse plumage may be omitted. A male mallard which Dr. J. C. Phillips confined in a cold room all summer did not attain the eclipse plumage but when brought into normal surroundings in the fall molted directly into the bright-colored dress usual at that period. I have studied adult male ducks affected by a sickness from which they recovered but that served to retard the plumage change so that the summer molt

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was omitted. In the fall they molted into bright plumage without the intervening stage of an eclipse dress.

The strange and aberrant forms that feathers may assume are mainly ornamental and may be special plumes confined to a single sex. Occasionally the barbs of a feather show little differentiation for more or less of the length of the shaft. This is true of the seemingly waxen red tips of some of the secondaries and rectrices in certain individuals of the cedar and Bohemian waxwings; strangely enough the first feathers of the nestling bird may have this peculiarity. Of a similar nature are the broader, hornlike or scalelike feathers seen in the curl-crested toucan (*Beauharnaisius beauharnaisi*), and in a cuckoo from the Philippines (*Lepidogrammus cumingi*). Other aberrations include the plumes found in males of many birds of paradise; the aborted head plumes of a helmet bird from Borneo (*Pityriasis gymnocephala*); the tail of the Reeves pheasant, which may reach six feet in length; and that of the Japanese silky fowl, the feathers in which, by some secret treatment, continue to grow without molt until they attain a length of from twelve to twenty feet.



Adult female green-winged teal, showing method of wing molt in which all the flight feathers are renewed simultaneously. Photograph by Alexander Wetmore. Courtesy of the Bureau of Biological Survey

CHAPTER III

COLOR AND ITS ARRANGEMENT

IN spite of the dull appearance of many avian species, birds, as a class, are characterized by greater brilliancy of color than any other group of animals. The resplendent-hued tropical fishes compose but a small fraction of all fishes, and bright-colored lizards, turtles, snakes, and amphibians are much more exceptional in their respective groups. Few mammals are endowed with brilliancy of color. Only among insects do birds meet serious rivalry in beauty and variety of color; but here their larger size gives them the advantage and, except for a few giant moths and butterflies, birds eclipse their insect rivals. We may unhesitatingly, therefore, assign to birds pre-eminence in color in the animal world (see Plates 28 and 41).

Three factors determine the coloration we see in feathers: First, the presence of pigment; second, refraction of light due to the outer conformation of the barbs or barbules; and, third, both pigmentation and refraction.

The pigments are divided into the fatty pigments, called the lipochromes, and the black pigments, called the melanins. Red, known scientifically as zooerythrin, is the most common of the fatty pigments and is seen at its best in such birds as the flamingo, the scarlet ibis, the scarlet and summer tanagers, the cardinal, certain parrots, and the cock of the rock. It occurs in the form of finely divided particles, which, when the feather is first formed, may be held in solution in an oily fluid and which in some birds may permeate also the fat of the body. Thus

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the fat underlying the skin of the cardinal and scarlet tanager is tinged a deep orange, in contrast to the yellow fat of sparrows and warblers which do not possess a red pigment. This zooerythrin in birds resembles in structure the red pigment of crabs and lobsters, and seems to depend for its formation upon certain elements in the food of the species concerned. Flamingos and scarlet ibises kept in captivity often fade in color with successive molts until they are bleached almost to white, but if fed on shrimp when the feathers are being renewed they may retain their brilliance of plumage.

Yellow pigment, known as zooxanthin, is allied to the red but has a somewhat different chemical composition. It is seen to good advantage in the yellow species of orioles and the yellow-headed blackbird. The head color in the latter, when the new feathers are first grown, is deep orange, darker in some individuals than in others; but after the feathers mature the orange color bleaches to a light yellow or in some individuals almost to white.

The dark pigments or melanins occur in small particles which are permanently fixed and cannot be dissolved by chemicals. This characteristic distinguishes them from the fatty pigments, which may be dissolved by treatment with alcohol, ether, chloroform, or other chemical reagents, depending upon their form. The size of the pigment granules in the melanin series has much to do with the shade of color produced. For example, it has been found that in the tumbler pigeon, a variety of the domestic pigeon, one and the same pigment may produce a black, brown, slate, or silver hue, according to the form, size, and abundance of the pigment granules.

Leaving the pigments of birds to consider what are known as their structural colors we find ourselves in a world of sham and pretense, as the colors apparent to the eye are found on analysis to be quite different from what they seem. For the greater part, they have as a basis some relatively dull pigment with an overlying layer of feather

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structure whose arrangement serves so to refract the light as to break it up into brighter colors.

Structural colors may be divided into two classes, metallic and nonmetallic. The metallic colors, characterized by a sheen like the reflection from polished metal, are produced by an abundance of dark pigment overlaid by a dark sheath in the tiny divisions of the feather called the barbules. In some types the metallic light is reflected from a highly polished surface; in others, well illustrated by the green of the sacred trogon or quetzal of Central America, the light is broken up by minute lines on or under the surface of the overlying sheath. In metallic reflections the color varies with the angle of the light under which it is examined, changing with the position of the object relative to the eye of the observer. To ascertain the true shade of the underlying pigment in such feathers, hold them so that light shines through, or pound them to destroy the reflecting surface, when the pigment will show in its true color.

The nonmetallic structural colors are very common. White feathers—where no pigment whatever is present, the white appearance being due to a refraction of the light in the barbules—illustrate the simplest of them. Examined closely under the microscope, the barbules are seen to be minute processes, flattened, and entirely colorless. If immersed in balsam, which destroys their refractive power, they become transparent and the white disappears. In the shafts and barbs, the larger divisions of the feather, the horny substance, called keratin, that composes the outer sheath is made up of numerous elongated cells, which, though colorless themselves, reflect light in such a manner that they appear white. These cells are impermeable and still show white when immersed in fluid.

Blue is an excellent example of the nonmetallic structural group of colors in birds, as it is of common occurrence and never appears as a true pigment. A typical blue feather from a blue jay, in which the barbs and barbules carry

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the color, has the following structure: A transparent, colorless outer sheath of keratin from ten to fifteen microns thick (a micron is the thousandth part of a millimeter, or about one twenty-five thousandth of an inch) serves seemingly as a protective covering; beneath this occurs a layer of polygonal cells about fifteen microns in diameter, also without color; finally, the central part of the barb consists of many minute, closely packed cells containing a dark, granular pigment deposited mainly in the cell walls. The blue appearance of the feather results from the breaking up of the light reflected from the dark cells by the overlying polygonal bodies. Truly a complicated arrangement.

Green in birds rarely occurs as a true pigment, being known in this form only in the feathers of a few cuckoos and of their African relatives, the plantain eaters. With these exceptions, green is a structural color resulting from a modification of the arrangement that produces blue. In the green feathers of parrots, for example, the feather structure is essentially like that described above for the blue of the blue jay except that the outer horny sheath is transparent yellow instead of being colorless. The blue produced by the basal pigment and the overlying polygonal cells is modified to green by the overlying sheath of yellow on the same principle as that by which the artist mixes blue and yellow on his palette to obtain green. Scrape the web of a large green parrot feather carefully with a very sharp knife and the resulting powder will prove to be distinctly yellow, while the web of the part of the feather that remains after the outer sheath is cut away will appear blue.

Birds exhibit variation from their usual coloring most commonly in the form of albinism—the condition in which feathers, ordinarily colored, appear partly or wholly white. Albinos may occur in any species of bird but are sufficiently rare always to attract attention. So much interest do white blackbirds, white crows, albino robins, and so on

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stir up, that they are much more frequently reported than would be expected and specimens of them are often sent to museums. The albinism may be confined to one or two feathers in the plumage, or may affect the entire bird, in which case the eyes may appear pink. Briefly, albinism results when for some reason pigment is not formed as the feather develops, and the white appearance is due to the structural refraction of light explained above. In a way albinism is a diseased condition.

The reverse of albinism is melanism, in which an excess of dark pigment makes the feathers appear sooty or black. Melanism occurs commonly in certain hawks, which have light and dark phases. The light phase is supposedly the normal one, as birds of this kind are more abundant, while only occasional individuals are brown or nearly black. The ferruginous rough-legged hawk (see Plate 13) of the Western States supplies us with a familiar example of this type of coloration, the melanistic specimens being frequently deep chocolate-brown. Many melanistic individuals appear so strikingly different from the normal phase that naturalists have sometimes erroneously considered them distinct species.

What might be considered a combination of albinism and melanism, in this case working in a normal manner, occurs in the little blue heron, in which species the young are white while the heavily pigmented adults are slaty-blue.

Xanthochroism, a rare condition of superabundant yellow color, occurs occasionally in parrots. Normally green parrots which show yellow feathers are usually, if not always, victims of a form of albinism in which the underlying pigment in the feather is lacking but in which the external sheath remains yellow and determines the feather's color. The common grass parrakeet or budgerigar of Australia, which is now reared abundantly in captivity, normally has most of the plumage bright green. Occasional individuals, however, are albinistic in the pigment layer, thus appearing yellow; while more rarely

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the albinism occurs in the outer sheath and the underlying pigment remains normal, so that the birds appear blue.

Erythrisms, or an excess of red, is still rarer in birds. It occurs regularly in the screech owl of the eastern United States, which has distinct gray and red phases. Curiously enough the red phase is restricted to the subspecies of the common screech owl found in the states east of the Great Plains, the various subspecies found to the west of that region being always gray.

Many ornithologists believed until comparatively recently that some birds had the power to change the color of part of their feathers after these structures had become fully formed. They thought that in some mysterious way new pigment entered at the base of the quill and permeated the web, or that an amoebalike blood cell (wholly imaginary, as there was absolutely no proof of the contention) invaded the barbs and barbules by the same route and devoured the old pigment cells, replacing them by new ones of a different color. Thus they accounted for such a seasonal change as takes place in the snow bunting, whose back is light in its winter dress and very dark in its summer dress. Similar agencies were called upon to explain the summer changes of plumage in male ducks, and many other seasonal differences in color in birds. Careful studies have shown, however, that a feather when fully matured is a dead structure, capable of change in color only through fading and wear. When the feather is fully formed the pulp through which the feather derives its nourishment during growth retreats from the quill at the base, leaving behind a series of horny caps—little partitions of membrane—which effectually cut off entrance of any further coloring or nutritive matter and thus positively prevent any change in color from new pigment.

The explanation of the color change in the snow bunting appears simple enough if we examine the feathers. Only the external portions of the feathers on the head and rump prove to be brown, the basal portions being white.



Snow buntings (*Plectrophenax n. nivalis*) in winter (left) and summer (right) plumages

PLATE II



Killdeer (*Oxyechus v. vociferus*), a species of plover, on its nest, made in a depression on the ground.
Photograph by Dr. Frank N. Wilson

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Similarly, only the exposed tips of the feathers of the back are brownish or buffy white, while the bases are jet-black. As spring advances the tips of the feathers wear away, leaving the head and rump white and the back completely black, producing an astounding alteration in appearance. A comparison of unworn and worn feathers serves easily to demonstrate what has happened (Plate 10). A change of similar kind may be observed without difficulty in the male English sparrow, whose dark throat patch becomes in the fall much obscured by grayish tips on the feathers. As the breeding season approaches these light tips wear away, leaving the black marking fully exposed and considerably altering the appearance of the bird.

Some species of waterfowl, particularly ducks, snow and blue geese, loons, and phalaropes at times may exhibit abnormal reddish or reddish-brown stains. These are most common on the head and undersurface, and result from the deposition of iron as ferric oxide on the outside of the feather. In the shallow pools of the tundras of the far north, and in many ponds in other regions, the bottom mud is frequently covered with a bright reddish-brown deposit of this same ferric oxide. We can easily understand how water birds swimming and feeding in these waters would be stained with this material. The iron is tenacious and adheres permanently, so that only a molt can free the bird of the stain.

The natives of some parts of Brazil produce an abnormal coloring in parrots and other cage birds by rubbing their heads, during the time when new feathers are being grown, with a secretion from the skin of a toad. This treatment changes green feathers to yellow. The birds thus modified retain this peculiarity of plumage until the next molt, and are known as *contrafeitos* or counterfeits.

A more common artificial color change consists in the production of orange-colored canaries, a species in which the yellow tint is due to a fatty pigment. The method was discovered by certain breeders of canaries, who for a

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long time guarded their secret jealously. It involves, however, merely the addition of sweet red pepper to a special food given a yellow canary when molting and growing new feathers. The blood absorbs the red from the vegetable product and passes it into the developing feather, giving the usual yellow a distinct orange tint. The orange may be deepened by protecting the bird from strong light until the feathers are completely grown and the color is set. The handsome shade of orange produced by these methods persists, of course, only until the next molt, when the normal yellow plumage is resumed unless the red-pepper treatment is repeated.

Few birds are plainly and uniformly colored; the vast majority exhibit a pattern which may be relatively simple or highly complex. Examination of large numbers of birds and mammals seems to show that pigment is laid down in definite areas. For example, many species of plovers have a dark ring about the neck (Plate 11). Many kinds of birds, from sparrows to ducks, reveal dark patches on the sides of the head, or definitely marked colored areas occur on the sides of the body; for example, the brown of the male chewink or of the chestnut-sided warbler. Similarly we frequently find light or white markings indicative of nonpigmented areas in certain locations; examples are the superciliary stripe above the eye in the song sparrow, or light areas on the sides of the body and elsewhere (Fig. 4.)

After careful study of a large number of species Dr. Glover M. Allen has found the pigmented areas in birds so definitely arranged that there seem to be six main points of centralization. The first of these is an area in the center of the crown, and the remaining five occur in pairs located on the cheeks, the sides of the neck, the shoulders, the sides of the body, and the rump. This theory considers the wings as projections from the shoulder areas and the tail as continuous with the rump. In uniformly colored birds, like those species of crows or ravens which are



Flicker (*Colaptes auratus luteus*) at nesting hole. The bird rests in typical woodpecker manner, clinging with sharp claws and bracing with stiffened tail. Photograph by Dr. Frank N. Wilson

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wholly black, these patches of color centralization entirely coalesce. In birds with much white coloring, like the old squaw duck, pigmented areas often outline clearly the position of these patches.

Partial albinos furnish proof of the existence of these definite centers for the distribution of pigment, for in

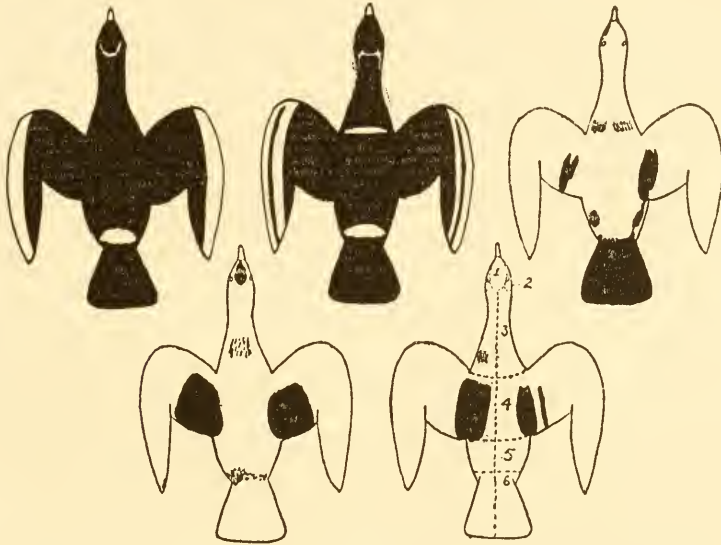


FIG. 4. Diagrammatic representation of the pigment areas in the domestic pigeon. After Glover M. Allen

them the abnormal white feathers usually appear near the junction of two of the pigment tracts. I once examined the heads of a large series of black-capped and Carolina chickadees (*Penthestes atricapillus* and *P. carolinensis*), species normally with a wholly black crown, and found a number with one or more white feathers in this area. In each instance the abnormal white feathers were located at the junction of the auricular and crown patches. The mountain chickadee (*Penthestes gambeli*) always has a white stripe in this same line on either side of the crown, a suggestive similarity.

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The reason for the existence of these six pigment areas remains obscure. It has been suggested that they correspond in a way to important nerve centers. Thus the crown patch centers about the position of the pineal eye—a median, unpaired eye found in the center of the top of the head in some fishes and reptiles and in embryo birds; the auricular patches surround the important fifth and seventh nerves; the shoulder patches are near the nerve centers known as the brachial plexus; and the rump patches overlie the lumbar plexus.

Certain color patterns may have a very definite physiological explanation. Regularly barred plumage, as seen in the barred back of a flicker (Plate 12) or the closely barred flank feathers in a male mallard, where light and dark markings alternate regularly, suggests this. According to Dr. Oscar Riddle's theory such alternation of color is due to differences in metabolism between night and day. Pigment is formed directly from the blood. During the day blood pressure is high and pigment deposition heavy and rapid. During the night blood pressure is much lowered, causing a corresponding slackening in the deposition of pigment. As feather growth is rapid and continuous the result is a series of dark areas formed by day and paler areas formed by night. This theory receives support from the fact that light fault bars may be produced artificially in feathers by the administration of amyl nitrite, a drug that reduces blood pressure. For the formation of feathers wholly of one color the pigment supply of the blood must be rich and constant.

Much discussion has arisen as to whether the barred or the striped pattern is the older form. The striping of young grebes, ostriches, and similar birds low in scale of development has weighed heavily as evidence in favor of the stripes. But if we accept Riddle's theory that fault bars are due to fluctuating blood pressure we must suppose the crossbarred pattern to be more primitive than the striped one, as it would develop naturally from fluctuation



Ferruginous rough-legged hawk (*Triorchis regalis*), of western North America. This species, like many related hawks, has light and dark color phases

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of pigment supply and could become fixed in certain groups of birds through operation of the laws of heredity. The spotted pattern arises from the partial breaking up of crossbars, while the streaked one may result from a union of such of these spots as lie along a line at an angle to the original bars.

One remarkable feature of color pattern is its persistence and ability to run true to form. Many birds acquire their different plumages in a regular sequence of color patterns which differ successively from one another until the adult stage is attained. These stages ordinarily are constant in successive generations and the pattern of the final feather remains uniform. Thus if we pluck a feather we will usually find the one that replaces it remarkably similar. Thanks to this continuity the remarkable complex feather patterns found in such birds as the Argus pheasant, the peacock, and the whippoorwill remain constant from generation to generation (Plate 14). Enforced renewal, however, may exhaust the feather germ so that if one feather is removed for two or three successive growths apart from the regular renewal at molt the last plume produced may be paler than normal or may have a less continuous pattern.

Within general limits the feather germ seems to control the pattern and color. Prof. C. H. Danforth has found that a piece of skin from a white leghorn chicken grafted on a barred plymouth rock continued to produce white feathers entirely different from the regular barred type of adjacent areas. Only rarely did a mosaic feather appear that attempted to combine the color characters found in these two races of fowls. However, the form of the feather seemed definitely subject to the influence of the endocrine glands, as skin from a leghorn male grafted on a plymouth rock female produced feathers characteristic of a leghorn female, distinctly different in shape from those it would have grown in its normal situation.

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A bird's coloration may be either directive or protective. The brilliant coloring of a male cardinal, wood duck, or scarlet tanager must be considered directive, as it is designed to attract attention, particularly from birds of its own kind. Such a brilliantly marked bird escapes his enemies by skulking at any alarm. To consider the highly conspicuous red of the flamingo as in any sense protective is foolish. The bird realizes this and frequents broad mud flats or open lakes where it can see for long distances and so escape approaching danger. No one who has attempted to stalk flamingos on an open shore can have any illusions as to this bird's lack of trust in the concealing possibilities of its bright plumage.

Though bright color patterns have been styled directive, conspicuous might be a better term. Certain patterns of striking color which are wholly or partly concealed when the bird is at rest are, however, truly directive; for example the red or orange crown patches of the kingbird (*Tyrannus tyrannus*). The colored areas may be present in both sexes or in the male alone, according to the species. Quite a number of birds, like the junco, vesper sparrow, and meadow lark, have white or partly white marginal tail feathers, while the central ones are wholly dark. Some display these white margins prominently in flight or show them when nervously opening and shutting the tail while at rest. We must suppose that such markings are designed to attract attention. Where the mark is confined to one sex it may be assumed to represent a sexual display; where both sexes possess it its purpose may be to hold parties of the same species together, or to attract individuals to others of their kind. The latter supposition is well substantiated by the Aleutian sandpiper. During much of the year this species inhabits rough, pebbly, or rocky beaches, where its dull color renders it practically invisible. As other Aleutian sandpipers pass in the air, those on the beach may suddenly extend one wing straight up and then fold it, sending out a brilliant flash of white



Whipoorwill (*Antrostomus v. vociferus*), a strictly nocturnal species, generally known only from its calls.
Photograph by Dr. Frank N. Wilson



Screech owl (*Otus asio naevius*) simulating the bark of the hemlock tree in which it rests. Photograph by Dr. Arthur A. Allen

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from the undersurface, to which their flying companions instantly decoy.

A great many birds have mixed patterns of gray, brown, and dull black which harmonize well with their surroundings and so make them inconspicuous. Such birds are said to be protectively colored. This coloration is especially characteristic of ground-inhabiting species but extends to many tree dwellers as well. The screech owl in the gray phase passes for a bit of bark-covered wood as the bird rests with feathers drawn close to its body and its eyes closed (Plate 15). A nighthawk at rest on a branch resembles a swelling on the limb; a whippoorwill on the ground is almost invisible (Plate 14); and a brown creeper on a tree trunk blends so with its background that it is not noticed until it moves. The least bittern poses with bill in air and streaked breast toward an intruder so that it merges well with its background of rush stems (see Plate 31).

The resemblance of the color pattern to the background, though seen in such ground inhabitants of woodland areas as the ruffed grouse, is best illustrated in those that live much in the open, like the Savannah, Henslow's, and grasshopper sparrows, whose streaked backs blend so harmoniously with their background that they creep about unobserved. Almost every island of the western Aleutian group has a distinct form of rock ptarmigan. The islands are of two types, one high and rocky, with much of the ground covered with moss, and the other low and flat, covered with grasses that show yellow and brown for much of the year. Dark forms of ptarmigan inhabit the high, rocky islands, where the background is dark, and pale forms the low, grass-covered islands, where the background is light.

Protective coloration is of special benefit during the breeding season, when the necessity of incubating the eggs or hovering the young binds the parent bird to one spot (see Plates 14 and 26). Likewise must young birds which

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are weak and more or less helpless depend on it, as without it they would stand small show against their enemies. However, some authors have placed too much emphasis upon protective coloration, as it cannot be assumed that all types of coloring protect. Many tints, as has been demonstrated, are attractive rather than protective. Bright-colored birds realize the value of remaining still to avoid notice, especially when at a distance from an intruder. Though the female rose-breasted grosbeak in her streaked dress is protectively colored when on her nest, the absolute reverse is true of her strikingly colored, black-and-white spouse with his red breast mark, when he attempts to share the duties of incubation. His devoted attention and assistance may easily result in the destruction of his home.

CHAPTER IV

ANCESTORS AND ANCESTRY

THE fossil record of the birds of past geologic ages is a broken one. In contrast with the approximately 25,000 living species known, we have record of only 800 fossil species, not including the few of forms which still survive and whose bones are preserved in deposits of the Ice Age. Our knowledge of many fossil species is limited to fragments of a single bone; and from this we must attempt to build up a sketchy picture of the entire animal, basing it, of course, on parallelism with existing species—a procedure which is justified by the established fact that adaptation for flight has restricted form in birds to narrow limits of variation.

Considering the number of living species and the abundance of individuals in each species it is strange that fossil bird records are so scarce. Estimates of abundance can not be very exact, but statistics of birds shot as game may give us some idea of the unquestionable magnitude of their number. Dr. Joseph Grinnell states that during the winter of 1910-11 five companies engaged in the handling of game in San Francisco sold 185,867 wild ducks of eleven or more species. According to figures obtained by Dr. J. C. Phillips more than 283,000 wild ducks of nine or more species were sold in New Orleans in the winter of 1913-14. These figures cover the traffic in only two cities. The Game Commission of Minnesota estimated the number of ducks killed in that State in 1919 as 1,804,000, and in 1920 as 1,180,000. From these and other figures Phillips estimates the ducks shot annually in the United States at

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more than six million individuals and possibly more than ten million, an indication of the enormous numbers of a dozen principal species that must exist to enable ducks to hold their own against such appalling slaughter.

Many small birds have wide ranges in which they abound, so that they much exceed the game birds in number of individuals. Grinnell estimates that one such species in the State of California, the Audubon's warbler, outnumbered at the opening of the hunting season all the game birds in the State combined. The millions upon millions of birds of all kinds that exist in the world becomes evident from these figures. And yet naturalists agree that in Europe, Canada, and the United States the numbers of the larger and more prominent species of birds have decreased decidedly in the past four hundred years. Some kinds, like the great auk and the passenger pigeon, have, of course, actually been exterminated; and all but a few of the smaller species that can inhabit cultivated lands have lost footing with the advance of agriculture.

Study of the records of climate, land area, and habitat (as indicated by fossilized plants) of the great Tertiary period, which preceded the Pleistocene epoch, show conditions apparently so favorable to bird life that we may assume birds to have been as abundant then as at any time in the historic period, and probably even more so and in greater variety, judging from the greater land area suitable for their existence. The Pleistocene, with its great glaciers that covered immense stretches of land in the Northern Hemisphere and so extensively restricted their range, brought severe pressure on many species and caused the extermination of an unknown number of forms.

Considering the uncountable numbers of birds that have existed over a period of millions of years, the few and fragmentary fossils found must be explained by the fact that bird bones are light and in consequence are usually destroyed before they are so placed that they may become fossilized. The relatively few instances in which the bodies

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or bones of dead birds are found in regions where living birds abound indicate that this destruction is the usual course. Most birds die through capture by some flesh-eating bird or mammal, while a smaller proportion become the prey of fishes, amphibians, and reptiles. Even when a bird succumbs to disease, its body is apt to be eaten promptly by some scavenger. In either event complete destruction of its remains is the rule. The skulls of birds are light and fragile, most of their limb bones are thin-walled and hollow-centered, and as the majority of species are of small or medium size they are often entirely consumed and their bones destroyed by the processes of digestion in their captors. Should any fragments remain they generally fall in places where they decay rapidly.

The fossil bird remains we have been able to secure consist mainly of the ends of wing and leg bones, with occasional vertebrae, fragments of the sternum, or bits of the skull. A good many are too broken to be identified. Only exceptionally have we found an entire bird skeleton intact.

Finally, even if a bird skeleton survives the hazards attendant upon fossilization, there is no security that the forces of erosion will not intervene to destroy it before it comes into the hands of the paleontologist. Yet in spite of these many handicaps our knowledge of fossil birds steadily increases. In 1884 only 48 fossil species were known from North America; while at present the list numbers about 170 which are extinct and more than 120 species whose bones are found in fossil deposits of the Pleistocene but which still have living representatives.

The oldest fossil remains of birds as yet known have come from quarries of lithographic slate near Solenhofen, Bavaria, the deposits dating back to the Upper Jurassic epoch, to which an age of 125 million years has been ascribed. In these rocks of fine-grained texture there came to light in 1860 the impression of a single feather. In 1861, in the same general area, there was found a partial

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skeleton showing leg bones, wing bones and a few other parts, together with distinct impressions of the wing and tail feathers. This specimen, which lacked the head, is now preserved in the British Museum, at London. It is known as *Archaeopteryx lithographica*, meaning "the ancient flying creature of the lithographic deposits." In 1877 the same region yielded a second skeleton practically complete, which came finally to the collections of the *Museum für Naturkunde*, in Berlin. While generally similar to the first the Berlin specimen differs so much in detail that it has been named *Archaeornis siemensii*.

These two strange creatures, fortunately preserved from a fauna of tremendous antiquity, show such reptilian characters in their skeletons that were it not for the feather impressions accompanying them they would hardly be considered birds. In life they were a trifle larger than the domestic pigeon, but more slender of body, and had a long series of tail vertebrae like that of a rat, forming a tail nearly as long as the head and body combined and with feathers projecting from each side for its entire length. The outer part of the wing, corresponding to the human hand, was divided into three fingers, entirely separate from one another and terminating in claws. The head was rather short and had no bill, and sharply pointed teeth armed the jaws. The wings had fairly long feathers, and indications point to a body covering of feathers. The form of the long tail suggests that these creatures flew with relative ease but not rapidly, and that they frequently resorted to sailing with spread wings and tail as do, for example, some tropical American cuckoos with long, broad tails and relatively short wings.

Presumably these two ancestral birds lived in trees or shrubbery. Their feathers and warm-bloodedness (which the feather covering implies) are their main avian characters, while the long tail, small number of neck vertebrae (nine), toothed jaws, and separate bones of the hand are distinct evidences of reptilian affinity. In truth these odd

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creatures appear to represent a stage in the evolution of birds only a step above the reptiles, and may be considered veritable missing links in the chain of evolution connecting these groups.

The long tails of *Archaeopteryx* and *Archaeornis*, which must have been rather flexible, would seem not to have furthered capacity for flight. In modern birds the tail, in addition to enlarging the supporting surface of the bird when on the wing, serves to direct and control flight and to check speed in alighting, being thus subjected to strong and sudden stresses. For none of these purposes would the lizardlike, flexible tail of *Archaeopteryx* and *Archaeornis* serve. The form of the tail changed, therefore, in succeeding ages, to that seen in the modern bird, which has the series of tail vertebrae greatly shortened and compact, with stiff feathers projecting from one level at the end—a form which gives the result desired in light weight combined with strength and rigidity.

Fossil birds of the Cretaceous period, which followed the Jurassic at a time estimated at seventy-five million years ago, exhibit two very distinct types of structure. One type belongs to a genus known as *Ichthyornis*, of which seven species have been discovered up to the present in the chalk deposits of western Kansas and Texas. The two best known, *Ichthyornis victor* (Plate 20) and *I. dispar*, about equal the domestic pigeon in size. These birds, while much more like modern birds than *Archaeopteryx* and its relative *Archaeornis* of the Jurassic, still show a number of highly primitive characters. Modern in their affinities were the long neck, the large and strong wings, and the heavy keel on the sternum or breastbone for attachment of the great breast muscles that control the downward stroke of the wing in which birds exert their maximum strength in flying. Harking backward were the long jaws set with many small, sharply pointed, recurved teeth, each one in a separate socket. The most peculiar structural character of *Ichthyornis* was the biconcave form

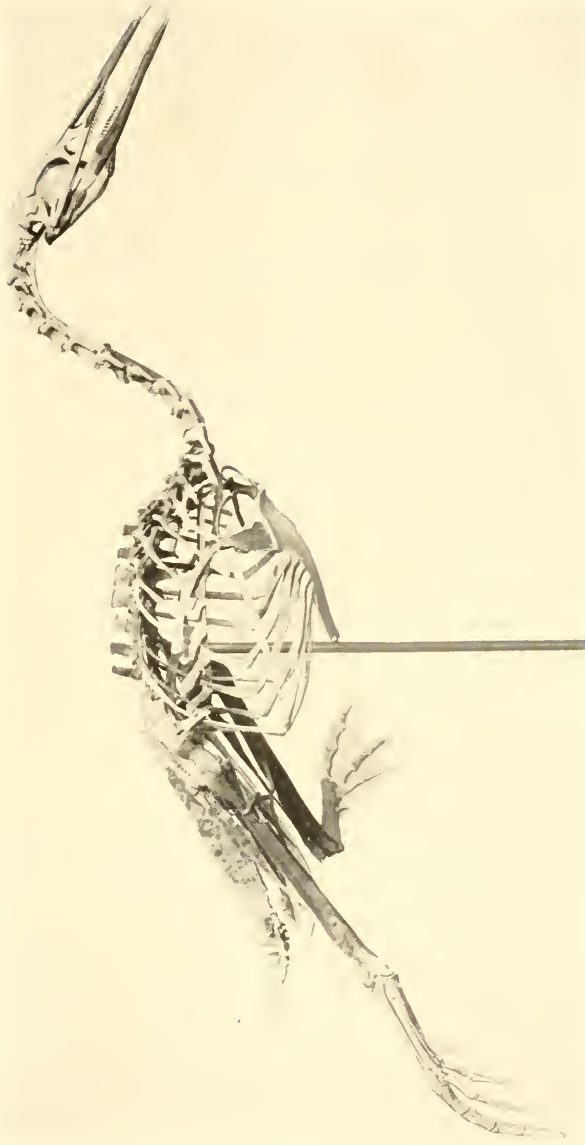
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of the vertebrae; that is, they were hollowed out on either end and connected by flexible cartilage and other tissue, as in fishes and some amphibians and quite unlike those of other birds. This characteristic explains the name *Ichthyornis*, which means "a fishlike bird." *Ichthyornis* was powerfully developed for flying, and had the strong wing and short, stiff tail structure found in modern birds. The teeth and the indication of strong jaw muscles suggest that it was a predatory form feeding perhaps on fishes or large insects. It was evidently near the line of development of our modern birds, though still so primitive in certain characters that it may not be considered directly ancestral to any existing group.

The second type of bird found in the Cretaceous is exemplified by the species of *Hesperornis* (meaning "western bird") and forms allied to it from the States of Kansas and Montana. *Hesperornis* (Plates 16 and 17) and its relatives were diving birds with greatly elongated bodies, strong legs, paddlelike feet, long necks, and jaws furnished with sharply pointed teeth set in grooves. The vertebrae had the saddle shape found in modern birds. The lower jaw had teeth along its entire length, but in the upper jaw they were limited to the central portion (maxilla) only, so that at this remote date there seems to have begun the reduction in dentition which has culminated in the smooth, toothless bills of modern birds. The largest species of *Hesperornis* were nearly six feet long.

All members of the group were entirely aquatic, living in the shallow seas which in the Cretaceous covered parts of the interior of the United States. They probably fed on fish, which they secured by diving, as the body form strongly suggests that of the modern, fish-eating loons. *Hesperornis* presents the most specialized development for aquatic life of any bird known, and was so adapted for existence in the water that it had entirely lost the power of flight. The wing had become rudimentary, being represented by the humerus alone, reduced to a slender,

PLATE 16



Skeleton of *Hesperornis regalis*, an extinct toothed diving bird from fossil deposits of the Cretaceous period in Kansas. Specimen in National Museum

PLATE 17



Restoration of the toothed diving bird *Hesperornis regalis*. The broad feet were set at such an angle that the bird could not stand erect. After F. A. Lucas

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curved bone possessed of so slight an articulation with the shoulder that it can have had but little function. The sternum was flat, without the keel found in flying birds for the attachment of the breast muscles used in flight. The hind limbs projected at right angles to the body, so that it is doubtful whether the bird could stand erect. From the form and position of the tremendously powerful legs and feet it seems probable that the bird at need could develop the speed and agility in swimming and diving of the living porpoises. If it ever ventured on land, it must have progressed by pushing itself along on its breast.

With the beginning of the next geologic period, the Tertiary, comes a definite change in the bird fauna. Toothed birds have disappeared, and the fossils found, while in some cases quite specialized, are generally similar to some group of modern birds, so that a good many from this period are placed in modern families. Species found in the oldest or Eocene beds are most peculiar, for example the *Diatryma steini* (Plates 18 and 19) from the lower Eocene of Wyoming. This great bird stood nearly seven feet tall and was specialized for a terrestrial life. It possessed strong legs, a heavy head with a great, arched beak, and small, almost aborted wings. Though classed provisionally near the cranes and the rails its exact relationships are not yet certainly understood.

Fossil bird remains become more numerous in Miocene and Pliocene deposits, toward the close of the Tertiary, and represent a variety of forms, many of them closely allied to living species. The list known from these beds in North America includes hawks, eagles, shore birds, boobies, gannets, shearwaters, auklets, limpkins, a parakeet, a goose, a dove, and various other forms, including a few fragments of perching birds. From the comparatively little known it seems probable that the bird life of the Miocene and Pliocene was even more varied than that of today. Students of climatology believe that the present strongly marked climatic zones of North America

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did not then exist and that a moderate and fairly uniform temperature obtained throughout the year at points much farther north than under modern conditions, greatly increasing the area suitable for subtropical life. Bird forms that now are considered subtropical, in the Miocene epoch extended north as far as Nebraska and probably farther. The fauna of tropical and subtropical areas is more abundant in species than that of temperate areas, so that we find greater diversity in these late Tertiary beds than now exists in the same latitudes in either the Old World or the New. From deposits of that time trogons, parrots, and many other subtropical forms are known from France, Germany, and elsewhere in western Europe.

The Pleistocene epoch or Ice Age, which immediately preceded the present epoch, has yielded a richer abundance of fossil birds than any earlier period. More than fifty extinct forms of birds are known today from the Pleistocene of North America alone. From extensive Pleistocene deposits at Fossil (or Christmas) Lake, in the arid section of Oregon, have come hundreds of bones of birds. Many are water birds, like grebes, coots, ducks, geese, and swans, but remains of grouse and other land birds are not lacking. A flamingo is the most unusual species in this assemblage, but its occurrence does not necessarily indicate a warm climate at the time in question, as we find a species of flamingo today in Patagonia, where even the summer weather is often cold.

Only a few miles from the center of Los Angeles occurs one of the most remarkable deposits of Pleistocene vertebrates in the world—that of Rancho La Brea. Here, during the Ice Age, outpourings of asphalt from the depths of the earth trapped unwary animals and, when decay had released their skeletons, entombed the bones in a bed of tar, where many have been preserved to the present time in the most perfect condition. These beds have yielded tens of thousands of bird bones, from which to date nearly sixty species have been identified with more still to be



Skeleton of *Diatryma steini*, a gigantic flightless bird found fossil in Eocene deposits in Wyoming. Courtesy of the American Museum of Natural History



The extinct *Diatryma steini*, from the Eocene fossil beds of Wyoming. Restoration by Erwin S. Christman.
Courtesy of the American Museum of Natural History

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determined. Two-fifths of the sixty known species are now extinct, among them several forms of great peculiarity. Remains of carrion-feeding species, like vultures, which would be attracted to carcasses of animals caught in the tar, are especially abundant. With them are ducks, herons, cranes, pigeons, condors, buzzards, hawks, eagles, falcons, horned owls, barn owls, ravens, crows, shrikes, and so on. The most curious of the extinct forms is a great vulture named *Teratornis merriami*, which is the largest of known flying birds, exceeding even the condors in expanse of wing.

Among the interesting finds of fossil bird remains in other lands, the great *Aepyornis*, or elephant birds of Madagascar stand among the first. They were flightless forms of which fourteen species divided among three distinct groups have been described, the largest being as tall as an ostrich, with much more massive legs. Many years ago natives of Madagascar who had come to the near-by island of Mauritius to purchase rum brought with them as receptacles for the liquor two enormous eggshells. These caused so much comment that they attracted the attention of scientists and were described under the scientific name of *Aepyornis*, which means "a bird as large as a mountain." Subsequent exploration in the south of Madagascar brought to light in some abundance bones and eggshells of the genus, usually broken, but occasionally entire. The genus may have become extinct within relatively recent times. The eggs of the largest species (*Aepyornis maximus*) measure approximately thirteen by nine and a half inches and have a capacity of more than two gallons. It may have been knowledge of remains of these great birds that caused Marco Polo to locate in Madagascar the fabulous roc of Sinbad's adventures detailed in the Arabian Nights.

Another flightless bird, the moa (family Dinornithidae), lived in New Zealand until recent times. It was still in existence when man came to New Zealand, for in certain

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places on South Island great kitchen middens containing quantities of bones from moas that had been cooked and eaten occur, and some evidence has been adduced to indicate that moas were known to the early Maoris. But others consider that the moa-hunters were an earlier race and that the moas became extinct before the advent of the Maori people. These flightless birds had no trace of wings. More than thirty species have been described, of which the largest was more than ten feet high. Abundant bone remains and a few eggs have been found, and in a few instances tendons have been preserved with the bones; more rarely fragments of skin have been obtained with feathers of a reddish-brown color still attached.

We see then from this brief account that fossil birds from the Tertiary do not differ fundamentally from existing birds, none of them being more peculiar in form than the penguins or the ostriches of today. In other words, all known Tertiary birds are clearly of the modern type. Only in the fossil forms of the Cretaceous and Jurassic do we find characters wholly different from any of those found in existing birds. These primitive characters are distinctly reptilian in nature and indicate certainly that reptiles are the closest relatives of birds and that birds originated from a reptilian ancestor.

Although structurally similar, in size of brain and in mental ability the bird has forged far ahead of its cold-blooded relatives, and so has multiplied while the parent reptilian stock has been slowly disappearing. The bird may, in a way, be considered the culminating point in reptilian evolution. Until recently birds have competed successfully with man for existence and so have flourished, though somewhat in the background of the evolutionary stage. The modern development of man, however, has outrun their powers of competition, so that in the past five hundred years they have on the whole steadily declined, having been preserved in fact largely by the protection afforded them by understanding human minds.

PLATE 20



Restoration of the toothed bird *Ichthyornis victor*, from fossil beds of the Cretaceous period. After O. C. Marsh

ANCESTORS AND ANCESTRY

The earliest birds known lived contemporaneously with dinosaurs—reptilian forms now extinct. With certain active birdlike dinosaurs birds had various structural affinities, such as hollow bones. Since the birdlike dinosaurs lived when birds were already in existence we must look into more remote ages for some generalized reptilian form from which both birds and dinosaurs may have come. The known group which most nearly fulfills the requirements is that of the Pseudosuchians, which lived in early Triassic times and which had a skeletal structure from which the form of skeleton and body characteristic of birds might have developed. Some students demur at this suggested origin, insisting that the true ancestral stock from which the birds branched off must be looked for in the still older Permian epoch of geologic history.

CHAPTER V

MIGRATION AND ITS STUDY

IN the temperate regions of the earth most species of birds move for the summer season to an area toward the poles and return for the winter to an area toward the Equator, traveling usually on a schedule of great regularity between their two homes. Comparatively few birds live the entire year within the narrow limits of the range they occupy during the nesting period. Even in tropical lands, though the number of strictly sedentary birds is large, some species migrate; and when we have more definite knowledge we will no doubt find more seasonal migratory movement among birds in these warm regions than might be supposed. In a vast number of creatures, migration appears to be a deep-seated instinct, an instinct so powerful that its promptings must be obeyed, though leading often to journeys for which the human mind can find no reasonable explanation.

Migratory movement is one of the activities in the life cycle of birds which is most evident, so that it attracts the attention of those with even the most casual interest in this group of animals. The literature on bird migration goes back to Aristotle, and in the last fifty years, particularly, so much investigating has been done along this line that our knowledge of the movements of many species of birds is considerable. Many explanations, some thoughtful and some fanciful, have been advanced to account for various phenomena connected with migration. Movements of cranes, geese, ducks, and other large birds that fly regularly by day were early understood, but the coming and

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going of smaller species which appeared or disappeared by night seemed almost magical and led to many curious beliefs. Further, to account for long journeys by the smaller species of seemingly little flying power was a problem of some difficulty. Peasants of southern Europe even to this day believe that smaller birds travel across the Mediterranean to Africa and return as passengers on the backs of storks and cranes.

Another common belief was that birds hibernated, passing the winter in a torpid state, hidden in caves or hollow trees or even submerged in mud at the bottom of ponds. In our own country this belief in hibernation has been frequently advanced to account for the sudden appearance and disappearance of swallows and of the chimney swift in spring and fall. Some people believed the sora rail changed overnight into a frog and thus passed the winter, until at the approach of spring it again assumed a feathered coat. A tale current among fishermen related with much circumstance how, in winter, they found lumps of torpid swallows in seines which had been drawn through ponds, and how the swallows when brought into warm rooms revived and flew about. Olaus Magnus, Archbishop of Upsala in the sixteenth century, describes the seining of swallows with fishes in this manner, and gives an illustration depicting the drawing of a net filled with mingled birds and fish. Men—even those with some scientific knowledge—put faith in such a phenomenon not more than sixty years ago. Papers on the subject were read before the French Academy and the Royal Society, in London. Finally John Hunter, a celebrated scientist of his day, tried the experiment of shutting several swallows in an outhouse in which he had placed tubs filled with mud and water and planted with rushes in the hope of getting the birds to hibernate. Their death from starvation was the only result. Others, though unwilling to concede the possibility of birds living beneath water, held to the theory that they did hide in cavities in the earth,

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and this belief persists today in some country localities. As a matter of fact, the state of suspended animation known as hibernation, though common in mammals, reptiles, and amphibians, is wholly unknown among birds; and their apparently mysterious appearance and disappearance are due to their return or departure as migrants under cover of night.

A belief in transmutation, or the conversion of certain species of birds into others as the seasons changed, also persisted for centuries after its promulgation by Aristotle, who, deceived by their seasonal appearances, believed that the redbreast, or European robin, changed in winter to the redstart. All the examples of transmutation recorded relate to species of similar size but different color whose movements are such that as one appears in migration the other disappears. The superstition that our sora rail in winter was transformed into a cold-blooded frog represents another misinterpretation of the facts, which are that soras migrate by night and that marshes tenanted by them in numbers one evening may on the following morning be left to frogs.

In 1703 an anonymous treatise on migration set forth in much detail a fanciful belief that migrating birds on leaving England flew directly upward until they reached the moon, a journey which required sixty days and during which the birds either required no food because of the rarefied element through which they passed or else lived on stored-up fat in their bodies. As there were no traffic obstructions in outer space the matter of requisite rest was easily explained by the supposition that the birds continued their upward flight while asleep! The author of this treatise, according to Hugh Gladstone, was Charles Moreton, an English minister who late in life removed to New England. Moreton's theory is antedated by one somewhat similar, written in 1636 by the Reverend Francis Godwin, who describes a "Wilde Swan" of the East Indies which, being a bird of strong flight, flew in

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migration to the moon. The good bishop fancied that "many of them together might be taught to carry the weight of a man," and published a figure which depicts a bearded gentleman named Domingo Gonsales seated on a crossbar suspended below an ingeniously arranged frame. Ten geese which are harnessed to the frame carry Gonsales above mountain and sea toward a distant moon high in the heavens. These geese, by the way, were supposed to have one foot webbed for swimming and the other with talons like a hawk's, with which they might capture small birds for food during their long aerial journey!

Leaving these fanciful suppositions for a more serious consideration of migration and its cause, we find the subject divided into two aspects: First, the impulses in birds that led to migratory movement in the beginning; and second, the controlling factors that today annually initiate and direct it. From our sketch of the history of birds it is obvious that migration as a factor in the lives of birds has had a period of time for its development so long as to be entirely beyond human comprehension, and that it is, therefore, futile to argue that any single agency has initiated all the complex migration movements known today. Migration as a whole expresses the influence of environment on all birds for the entire period of their evolution. Different types of birds must have undertaken migratory movement for different reasons, so that the basic original cause must be considered complex. Among its factors must be included variation in food supply, change in seasonal temperature, seasonal alternation of rainfall and drought, and modification of environment due to such profound influences as the advance and retreat of the northern ice during the Glacial period. In their effect some of these factors are closely interrelated; for example, cold or drought may influence food supply, but no one factor can be designated as the critical cause inspiring and explaining all migration.

Some have argued that all migratory birds have origi-

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nated in the south and have spread northward merely to find suitable breeding grounds, returning southward as soon as their young have been reared. Others postulate a northern point of origin for migratory birds, from which they have been driven by encroachment of ice and cold but to which they return each summer to nest, through love of birthplace. Again, it has been held that birds turn naturally to the region of greatest light, and thus travel north and south as the sun advances and retreats across the Equator; or that migration is a natural outcome of the ability to fly, the long migratory flights of many species being an expression of pleasure in skillful flying. While all of these factors may have had some effect in producing migration, it again holds true that no one of them has sufficient importance to stand alone as the basic cause of migratory movement.

Coming to the second aspect of the problem, the controlling factor that each year requires the various species of birds to migrate to their breeding grounds at the opening of the nesting season and to leave these areas when their young are on the wing undoubtedly lies in the cyclic nature of the life processes of each individual. The life of the bird moves in synchrony with the seasons, through a breeding period and a subsequent resting period. The physiological changes which take place with the coming of the breeding period are sufficient to bring the golden plover from its winter home in the Argentine Republic to its summer range in the tundras of the Arctic regions, or the long-crested jay of the Rocky Mountain region from a winter range in the lower hills to an adjacent breeding ground a few hundred feet higher. The wane of these same physiological conditions when their irresistible impulse has had its sway suffices to initiate the return to the winter home.

The hormones of the gonads, or sexual organs, are believed to be the catalyzers that produce the desired result. (A catalytic agent in chemical parlance is one that

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seems to do no work itself but by its presence makes possible definite reactions.) These sexual hormones then are not the actual cause of migration: they merely serve as the impulse to start the machinery that carries migratory movement through its proper course. The southward migration of young birds that have never nested must be accepted as a response to the same impulses that actuate the parents.

So vague is our knowledge of the origin and of the present^{*} actuating causes of migration that further discussion would not carry us to any more definite conclusion than we have now reached. It is of greater interest to pass on to the more exact information we possess regarding this remarkable phenomenon in different species of birds.

As already indicated, the majority of birds, such as warblers, small flycatchers, finches, sparrows, rails, cuckoos, vireos and a host of others, migrate mainly by night, appearing in abundance in a given locality one morning and perhaps disappearing before the next morning. The larger birds—hawks, shore birds, ducks, geese, cranes, blackbirds, pelicans, waxwings, bluebirds, jays—perform their migratory movements by day, and are regularly seen flying high overhead in the direction in which the season is moving them. On occasion many of these may travel by night also, urged perhaps by some imminent change in weather conditions.

The theory that birds do travel regularly by night may be tested occasionally during rainy evenings in September when small birds may be heard in multitudes calling from the threatening clouds above as they travel southward. Often the trained ear can pick out the voices of such friends as the woodland thrushes, yellowlegs, upland plover, or solitary sandpipers from the soft calls that drift down from overhead. Sometimes, also, on clear nights, if one turns a telescope or even a pair of powerful field glasses on the full moon, one will see at intervals the silhouettes of birds passing across its face. With powerful instru-

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ments it is even possible occasionally to identify, by some peculiarity in flight, the kind of bird seen.

Nocturnal migration takes place principally before midnight and immediately before dawn. By traveling at night the smaller birds win the protection of darkness against hawks and similar enemies; probably, also, timid species, such as wrens, ground-haunting sparrows, and warblers, and similar forms that live habitually under cover, feel safer in venturing into the open air at night than they would in the light of day. Another factor of perhaps greater importance is food supply. The stomach of any small bird killed for examination during the day is found to be filled with remains of the food that it has gathered through its almost incessant search. Digestion is very rapid, so that it is necessary for the bird to eat at short intervals to keep up the store of energy required for its active life. Should the smaller birds fly long distances during the day, arriving at some destination at nightfall, they would be forced to spend the night without food and so lose time the following day in feeding and resting. By flying at night and arriving at the objective point near dawn they can rest for a period, then feed and rest during the entire day, thus recuperating so that if necessary they can resume the migratory flight the following evening.

The early observers, thinking that in some way flight was easier in the rarefied medium of the upper atmosphere than nearer the earth, believed firmly that the majority of birds traveled at distances above the surface as great as 15,000 feet or more. For this belief, however, there is no basis in fact, as recent observations made from airplanes reveal that most birds fly at an elevation of less than 3,000 feet, and that it is exceptional to see birds above an elevation of 5,000 feet. It is true that most of these observations have been made during the day, but if it is not advantageous to fly at higher altitudes by day, no reason exists to suppose that it would be so at night. Birds have often been observed migrating across areas of open sea by



Nighthawk (*Chordeiles minor virginianus*), an American goatsucker that is regularly active by day.
Photograph by Dr. Frank N. Wilson

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day at distances above the waves varying from a few feet to not more than five hundred.

The speed of birds in flight is another matter that has been frequently exaggerated. Years ago Gätke, studying avian migration at Heligoland, became obsessed with the idea that most birds performed the greater part of their journey in a single night, and from this mistaken premise concluded that they must travel at rates of speed as high as 180 to 240 miles an hour! The wide currency given this wholly erroneous conclusion has unfortunately deluded many readers. In the past fifteen years reliable data on the speed of flight in various species of birds has accumulated from observations of birds traveling parallel to automobiles, from observations made by theodolites designed to enable anti-aircraft stations to estimate the speed of airplanes, by readings from airplanes, and by timing flight over measured courses by means of stop watches. From these records it appears that such diverse forms as herons, the slow-flying kinds of hawks, horned larks, ravens, and shrikes fly at twenty-two to twenty-eight miles an hour, starlings at thirty-eight to forty-nine miles an hour, and geese and ducks at forty-two to fifty-nine miles. Most small birds range between twenty and thirty-seven miles. Swifts seem to be the fastest flying birds known. In Mesopotamia a species of swift (apparently the common swift of Eurasia) passed an observing plane and circled about it with ease when it was traveling at sixty-eight miles an hour, indicating a rate of seventy to a hundred miles for the birds. Though no definite check on the question has been made it is certain from observation that the white-throated swift flies with equal speed. The peregrine falcon, or duck hawk, readily overtakes fast-flying pigeons, shore birds, and ducks, capturing them in mid-flight with ease, so that it must develop a tremendous speed, probably eighty to a hundred miles an hour. E. C. Stuart Baker timed two species of small swifts (*Chaetura nudipes* and *C. cochinchinensis*)

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over a two-mile course with stop watches and found that on occasion they were able to cover the distance in thirty-six to forty-two seconds, or at a rate of 171.4 to 200 miles an hour. This, however, must be considered exceptional and a rate not to be maintained for any great distance.

In migratory flights most birds apparently progress at a speed of twenty to fifty miles an hour, and the long journeys made by some are accomplished by moving for long hours at a steady rate rather than by tremendous bursts of speed for short distances. Observations of birds flying by night, made at lighthouses and other favorable points, have shown that migrants pass in regular unhurried flight. If we postulate ten hours as a fair period for a nonstop migration flight over land, the speeds that have been cited would in that period carry the smaller birds from 200 to 270 miles, and ducks and geese from 420 to 590 miles. These are distances of magnitude, particularly when travel is in a direct air line, and would enable the birds to cover the ordinary migration route from Canada or the Northern States to the Gulf coast region, or even to Central and South America, in a relatively short time.

While many species of birds travel hundreds of miles to reach their winter homes, some mountain dwellers have merely to descend from the forests and meadows of the higher slopes to near-by lower levels to find comfortable locations for the winter, for a few hundred feet of altitude may correspond in difference of climate to several hundred miles of latitude. In our western mountains rosy finches, juncos, pine grosbeaks, and siskins regularly descend the slopes in fall and ascend them in spring. In the Great Basin I have seen violet-green swallows reach their mountain breeding grounds in May, only to retreat again to the lowlands when snow fell and covered the mountains, there to remain until the weather had moderated. Such journeys meant only a few miles of travel and were accomplished with ease.

The length of the migration route traveled by different

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species of birds varies within wide limits. Such birds as the cardinal, Carolina wren, and mocking bird remain throughout their lives within a range of small radius; they move about only to secure food and do not go to any great distance to nest. Contrast these with the eastern form of the golden plover, the classic example of a long-distance migrant. In autumn these plovers congregate in Labrador, then fly south directly over the ocean, past Bermuda, to the West Indies and northern South America, continuing to the open grasslands and coastal mud flats of the Argentine, where they spend the winter. In spring they return north, this time crossing the Gulf of Mexico to the United States and migrating up the Mississippi Valley to their breeding grounds. The western form of golden plover travels south in fall from Alaska to the Hawaiian Islands and the many other island groups of the Pacific, crossing hundreds of miles of open ocean in its journeys, or moves southward along the eastern coast of Asia as far as Australia, Tasmania, and New Zealand. The migration routes followed by the two races of golden plover are remarkably distinct one from the other, each covering a totally unconnected area of the globe.

Twenty-three of the species of plovers and sandpipers that nest in northern North America, many of them in the Arctic regions, range in winter from the southern United States through the West Indies to South America, ten of them having their winter homes entirely within the latter continent. Such forms as the golden plover, Baird's, pectoral, and buff-breasted sandpipers, and the upland plover (see Plate 5), go far into the south temperate regions, some continuing into southern Patagonia. Why these birds should cross the Equator and fly many hundreds of miles farther than would seem necessary to find a suitable climate and feeding grounds for the period of the northern winter is one of those mysteries for which no apparent explanation exists. After crossing the Equator these birds move south in September and October with the

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advance of the southern spring. The approach of cold weather in the south temperate zone in March and April sees their departure for the north, when after crossing the Equator they again continue to their breeding grounds with the opening of the northern spring. Thus they follow the swing of the seasonal movement throughout their entire flight.

Several familiar species of our smaller birds make the long journey to central and southern South America each year. The bobolink, in the sparrowlike winter dress in which it masquerades as a "reedbird," spends the winter in the area extending from southern Brazil to northern Argentina. It lives in flocks in marshy areas. In Argentina it is trapped and sold as a cage bird under the name of "charlatan," from the pied coat of the male in breeding dress. A few barn and cliff swallows, yellow-billed cuckoos, olive-backed thrushes, and nighthawks (Plate 21) also reach Uruguay and Argentina. The true extent of these long migrations is realized to the fullest when the naturalist from North America encounters these familiar friends amid such strange and distant surroundings. The scarlet and summer tanagers, red-eyed vireo, black-and-white, blue-winged, yellow, and golden-winged warblers, red-start and numerous other birds reach Colombia and Venezuela but do not go farther south.

The Arctic tern is famous as the species with the longest migration route known; it nests from the coast of Massachusetts north to northern Greenland and Alaska, and spends the winter off the shores of the great Antarctic continent, south and east of the Falkland Islands. Recent observations indicate that its migration flights take it from the shores of New England east across the Atlantic and down the west coast of Africa to its winter home. This species of bird has more hours of daylight in its life than any other animal known. Only in crossing the Equatorial region does it encounter nights of long duration.

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The migration of birds that breed in the Southern Hemisphere, though studied but little as compared with that of birds that breed in the north, is extensive. Petrels and shearwaters offer the most interesting examples. The sooty shearwater nests on islands near New Zealand and Cape Horn, and in May travels far northward through both great ocean systems to southern Greenland and the Kuril and Aleutian Islands, returning south to breed in September. The slender-billed shearwater migrates from breeding grounds in South Australian and New Zealand waters through the western Pacific, mingling in Alaskan waters with the sooty shearwater in flocks of tens of thousands of individuals. The Wilson's petrel, the little Mother Carey's chicken seen during transoceanic voyages, also breeds in southern latitudes and comes north in March, April, and May, through the temperate oceans of the world with the exception of the North Pacific. These species of sea birds penetrate as far north of the Equator as some of the northern terns and shore birds travel south of it.

In temperate South America sparrows, flycatchers, wrens, swallows, goatsuckers, native plovers, and others migrate regularly from more southern latitudes, in Patagonia and the pampas region, toward the north, while along the flanks of the great Andes the same altitudinal movements up and down the mountain slopes take place as in the mountains of our own country.

Comparable migratory movements occur in southern Africa among native cuckoos, swallows, a swift, a roller, a wryneck, a falcon, a stork, a wattled plover, and others. These birds are supposed to winter in central Africa. The pennant-winged nightjar (a remarkable goatsucker, the male of which has two of the inner primaries in each wing so greatly elongated that they measure two and a half times the length of the bird from the end of the bill to the tip of the tail) makes regular annual journeys across the equatorial forests to the grasslands found north and

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south of it. Its movements are governed apparently by the seasonal swarming of the termites or white ants which form its main food.

Australia likewise has a small group of native species which migrate regularly from north to south with changing seasons. These include the roller known as the dollar bird, a cuckoo called the channelbill, the sacred kingfisher, the spotted harrier, the slate-breasted rail, swallows, bee eaters, and so on. New Zealand, lying farther to the south, has a number of migrant birds that come there in spring to nest and then go north in the fall to winter in Australia. Few of the migratory land birds of the Southern Hemisphere are known to cross the Equator, though, as has been observed, numerous northern species, in their migration flights to the south, reach points below the equatorial line.

The regularity that governs the seasonal movements of birds and the seeming ease with which young and old traverse long routes have resulted in considerable speculation as to the manner in which they are directed toward their proper destination. Various theories have been advanced; for example, that birds possess a magnetic sense whereby they are sensitive to the magnetic pole; that they possess a special nasal sense which enables them to identify wind currents and other meteorologic phenomena; that they move in association with regular winds; that they are influenced by the angle or direction of the sun and the light rays; that their distant objectives have a definite attraction or pull that draws the winged travelers to them; that they have an hereditary memory of the routes traversed so that fledglings can follow the routes as well as adult birds; that through a special sense they have direct perception of the point to be attained; that they advance by telepathy; or that they direct their movements by the positions of the sun and stars as human navigators direct the courses of vessels or airships.

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The diversity of these views emphasizes the complexity of the question, while their purely theoretical character shows that little is known regarding the matter. The problem has its practical aspect in the ability of the carrier pigeon to transport messages or to make racing flights over unknown courses. Two factors seem to be involved: First, the impulse, which may be termed a sense of direction, that drives birds over the proper course; and second, the recognition of local landmarks that guides them to descend at the seasonal home, just as it guides a pilot to bring his plane to earth at its airport. We can really say nothing definite about either of these complex factors.

Much of the great mass of information on migration that we have has come from observations of birds *en masse*—records of first arrivals, of the period of passage and greatest abundance, and finally of the last individuals observed where the species in question passes beyond the point of record. The great number of such recorded details has made it possible to understand the movements of the species as a whole, and many species have been so studied.

This method is now supplemented by that of banding certain individuals and then releasing them, which involves capture of the birds and the placing of a numbered band of aluminum on one leg (Plate 22)—the number, place, and date being carefully recorded thereon. Should chance later bring a banded bird to hand we have at once definite information concerning the movement and life of an individual as singled out from the mass of his fellows. With the steady accumulation of information from this source it becomes possible to plot the migration routes of individuals and so to indicate currents or channels of migratory movement in a vast sea of migration, continent-wide, in which hundreds of millions of birds participate. In addition to giving valuable data on migration, bird banding affords definite, incontrovertible statistics on the ages that individual wild birds attain, on their breeding

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and development, growth, and change of plumage, and in fact on all their living activities.

The first record of the marking of birds for a definite purpose is found in the writings of Pliny (in the first century A.D.), where he tells of the bringing of swallows from Volterra, in Tuscany, to Rome, and of their release after they had been marked with cords showing the colors of the winners of the chariot races in the capital, so that they might carry this information speedily to expectant watchers. There is also a report of a great gray heron, captured in Germany in 1710, which had several rings on the leg, one of which is stated to have been placed on the bird several years before in Turkey. In our own country, in 1803, the famous naturalist John James Audubon banded a brood of young phoebes on an estate on Perkiomen Creek, near Philadelphia, and the following spring had the satisfaction of finding two of these marked birds near the cave where they had been hatched.

Other sporadic attempts to mark birds so that they might be subsequently identified have included the use of little bells, bits of colored yarn, and indelible ink or paint on prominent feathers. In 1899, C. C. Mortensen, of Viborg, Denmark, began systematically to band storks, starlings, and a few other birds. In 1902 and 1903 Dr. Paul Bartsch of the Smithsonian Institution marked some black-crowned night herons in the District of Columbia with numbered bands that were stamped "Smithsonian," and from these birds were obtained a number of interesting reports when they were subsequently recovered at varying distances from Washington. The American Bird Banding Association was formed in 1909 and continued in operation until 1920, when its work was formally turned over to the Bureau of Biological Survey, of the U. S. Department of Agriculture. The Biological Survey had become interested in the possibilities of this method of study, partly through returns from a large number of wild ducks which I banded on its behalf in Utah from 1914

PLATE 22



A chickadee family (*Penthestes a. atricapillus*). The parent bird, at the left, has been banded, the aluminum band showing plainly on the leg. Photograph by Dr. Arthur A. Allen



Mourning dove (*Zenaidura macroura carolinensis*) with its flat nest of small twigs containing two eggs.
Photograph by Dr. Frank N. Wilson

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to 1916. At the present time the Biological Survey issues to properly accredited cooperators throughout the United States and Canada, numbered bands, bearing an appropriate address for report if the birds so marked should be recovered. These cooperators keep the central office informed of all birds banded, with date and place of release and any other pertinent information, data which are placed on file to be available should any of the banded birds be subsequently found.

Interest in bird banding continues in Europe also; but due to the many political divisions, language differences, and lack of close cooperative interest, it has been carried on there under a number of different organizations. In North America, on the contrary, there are at present more than 1,500 workers cooperating with the Biological Survey, and four regional associations have been organized better to carry on the work. Up to the present (1930), more than 800,000 birds have been marked since the Biological Survey undertook this work, from which have come a total of more than 30,000 records of subsequent capture. The number of birds handled increases steadily. Japan, also, began a system of bird banding in January, 1925, with the result that at the beginning of 1928 more than 32,000 birds had been banded, and two returns had come from near Manila, in the Philippine Islands.

To show some of the many worth-while results that have come from bird banding, I may cite records of mourning doves (Plate 23), banded in the north and killed later in the south, which have played an important part in court decisions. I have in mind in particular one of these doves which had been marked as a nestling near Philadelphia and which was later shot in southern Georgia. A Federal court in Athens, Georgia, tried a test case in order to decide whether or not mourning doves came under the ruling of the Federal Migratory Bird Treaty Act, which gives Federal protection to migratory birds. The trial went in favor of the dove, for the court decided, on the

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basis of records of three doves that had been banded, in addition to other evidence, that the mourning dove must be considered a migratory bird and therefore entitled to Federal protection. Mr. S. Prentiss Baldwin has found that house wrens may remain mated for an entire season, may change mates between second and third broods in one season, or that occasionally one male may start a second family with a new wife when spouse No. 1 has been duly established in the incubation of a setting of eggs. Many other studies of importance requiring identification of individual birds are in progress.

One July day in 1916, in the great marshes at the northern end of Great Salt Lake, Utah, I banded a number of snowy herons. The following March a peon in the little village of Mescaltitan, western Mexico, brought to a passing Japanese labor contractor a bit of aluminum which he had found on the leg of a heron he had killed to eat. The peon, who could not read and so could not decipher the characters stamped in the metal, had preserved the band from curiosity. The Japanese forwarded it to the Biological Survey in Washington and so completed the story of one of the herons I had banded in Utah the previous summer. In June, 1917, the American consul at Acapulco forwarded a second heron band taken at the Papagayo Lagoon, in Guerrero, and a third came in 1923, through the State Department, from Escuinapa, Sinaloa. These reports indicated very definitely that the snowy herons which nest in Utah migrate to the west coast of Mexico.

In these same Utah marshes, in September, 1914, I was crossing a stretch of shallow water in a peculiar type of launch designed to run at rapid speed over smooth clay mud barely covered with water, when I observed a pintail duck helpless from a sickness due to alkali, prevalent in that region. I gathered up the duck as we swept past it, took it to the laboratory a few miles distant, and restored it to health. A short time later, tamed by its

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remarkable experience with man, it was banded and released. For a month it lingered near, returning night and morning to be fed, until the laboratory was finally closed for the season. The following February this same duck was captured alive on the Salt Plains of northern Oklahoma, where it remained, the pet of its captor.

A purple finch (see Plate 53) banded July 28, 1922, at Sault Ste. Marie, Mich., returned to the same spot April 27, 1923, May 2, 1924, April 20, 1925, and May 8, 1926, having in each interim performed a migration to a winter home supposedly to the southward. Its return each season constituted remarkable evidence of its ability as a traveler. Several golden-crowned sparrows banded by J. E. Law at Altadena, California, returned for three successive winters to the same yard. This species nests in the far north, returning regularly to a winter home in the south.

The hurricane of the autumn of 1928, in its destructive passage through the West Indies, wrought havoc with birds. Reports came in of several banded common terns found dead that had been marked on the coast of Massachusetts the previous summer while still immature. A tern marked at Eastern Egg Rock, Maine, July 3, 1913, was found dead in August, 1917, at the mouth of the Niger River, in western Africa. Two kittiwakes, a small species of gull, banded on the Farne Islands, off the coast of Northumberland, England, were killed subsequently at Horse Island, Newfoundland, and Hamilton Inlet, Labrador. Another kittiwake marked at Umanaq, Greenland, was taken at Seal Cove, Newfoundland. Of two black-headed gulls banded at Rossiten, on the coast of Germany, one was taken subsequently at Bridgetown, Barbados, in the West Indies, and the other near Vera Cruz, Mexico. These are only a few instances of many records that have been obtained of the journeys of single birds, and indicate what may be expected from this type of study.

CHAPTER VI

HOMES AND THEIR LOCATION

THE homes of birds and their activities in connection with nest building and the care of their eggs and young interest more persons than any other phase of avian study, attracting more attention, even, than bird banding, in which interest is rapidly growing. Many leading scientists now occupied with shells, insects, mammals, or miscellaneous invertebrates to the exclusion of other branches, first had their interest in scientific matters aroused by the sight of the eggs of some small bird resting in the nest and were through this channel drawn into investigation and research of natural phenomena of various kinds.

In regions of equable temperature within the Tropics the nesting period is often irregular, the breeding season for different pairs or different species overlapping at times throughout a great part of the year. In areas away from the Equator, where seasonal limits are definitely marked, the general nesting period occurs in spring and early summer, so that the young birds are grown by the approach of fall. Certain exceptions to these general statements will be noted later.

Generally it seems to be the male who at the approach of the nesting season selects some tract within the limits of which his nest will later be located and defends it against encroachment from other males of his kind. While the breeding area of solitary species may include a fair-sized tract of grassland, thicket, or trees, that of gregarious forms which nest in colonies is frequently very small. At the first hint of spring the red-winged blackbirds of our North American marshes mount commanding perches on

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alders, willows, or dead cat-tails and proceed to sing of the nests that will later be located somewhere beneath them. Individual birds may be separated by spaces of only twenty-five to fifty feet, but within these limits they do not permit transgression by others of their own sex and kind. They give rapid and effective battle to drive away intruders on the singing perches.

In the South this selection of breeding territory may begin at the close of February, though actual mating may not come until April or May. During each of the cold storms that mark the advance of spring the males may abandon their singing and flock to more sheltered localities to appear once more on their accustomed perches when the weather moderates. Territorial limits among these birds and also among yellow-headed blackbirds appear especially well marked in semiarid regions of the Western States, where swampy areas suitable for them occur only as narrow bands of rushes at the borders of streams and lakes beyond whose immediate confines the land is dry and arid. Here the males may be distributed at regular intervals almost like sentinels.

The breeding territory of such gregarious species as the ground-nesting terns (Plate 24) may have even more definite limits. The sooty terns, which often breed in very large groups, are apt to place their nesting hollows only three to four feet apart. The exact distance seems to be governed by the pecking and sparring of adjacent males, who vigorously attack any individual that alights too near but do not run out more than a few steps in pursuit. Some of the gregarious weaver finches place their nests so that they actually touch and merge into one large structure.

Contrasted with these are many species which, though common and widely distributed, are solitary in habit and do not congregate in groups unless attracted by some abundant supply of food. The lark sparrow (Plate 25) locates in some stretch of grassland dotted with shrubbery,

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the wood thrush occupies an area of woodland, and the red-eyed vireo chooses certain trees or a little grove, each individual ruling over his selected area and fighting valiantly to drive out intruders of his own kind.

These battles often lead to the serious injury or even death of one of the contestants. Feathers fly and blood is drawn, and the struggle may be prolonged until both birds are exhausted. I have had two rival mocking birds fall at my feet, clenching each other closely with bills and feet, so intent on their quarrel that they refused to part until almost under my hand. Often special weapons are developed for these struggles, such as the spurs of male gallinaceous birds, the sharp claws of coots, or the knob-like projections on the wings of geese.

Sometimes the seasonal antipathy of male for male becomes ridiculous and may even lead to the injury of the bird, as when a robin or cardinal becomes obsessed with fury at his own reflection in a windowpane, and returns day after day to struggle futilely with a phantom antagonist against which he beats and struggles until he falls exhausted. This shadow fighting sometimes becomes so aggravating that the householder is forced to screen his window.

These struggles take place only between males of the same species or between those of closely related forms; where there is no particular conflict of interest, individual breeding territories of different species may overlap in a mosaic of great complexity. A pair of ruffed grouse (Plate 26) may occupy the ground space in a tract of woodland, while small warblers or flycatchers preempt the bushes and lower limbs above, and a vireo ranges in the higher branches. Above all these nesters some broad-winged hawk that feeds on rodents and so does not molest the other bird inhabitants may hold sway. At night the same sections may be given over to loud-voiced whippoorwills, and owls which on occasion prey on their diurnal neighbors.



A pair of Caspian terns (*Hydroprogne caspia imperator*) with their downy young. Photograph by Dr. Frank N. Wilson



Lark sparrow (*Chondestes g. grammacus*) with its nest and young. Photograph by Dr. Frank N. Wilson



Female ruffed grouse (*Bonasa umbellus*) on nest. Photograph by Dr. Frank N. Wilson



Eggs of the black skimmer (*Rynchops n. nigra*), laid without nesting material in a depression in sand.
Photograph by Alexander Wetmore

HOMES AND THEIR LOCATION

Selection of territory for a home may take place weeks before the nesting season arrives, as witness the black-birds in our marshes; or it may be followed at once by nest building, as is the case with the sandpipers and plovers, which begin mating immediately on their arrival in the northern tundras in order to take due advantage of the short season of warm weather available to them for the rearing of their young. The mating urge is the signal for unusual activity. The males among the smaller birds sing, grouse drum or hoot, and other species utter sounds which, though ridiculous to human ears, are sweet music to prospective mates, who come to listen and remain to be wooed and won. Strange and beautiful displays often accompany mating. Of such are the spreading of the long train of the peacock before his mate and the dancing of the male purple finch with feathers spread to show off his dress of soft, reddish tones. The mocking bird rises in the air with slowly flapping wings to display to the utmost the white markings in his wing and tail feathers. The red-tailed hawk for the delectation of his ladylove closes his wings and drops from a height of several hundred feet like a plummet, with air roaring through his plumes, checking his speed gracefully often just before reaching the earth. Other actions may appear grotesque, such as the male grackle strutting on our lawns with puffed-out feathers and widely expanded tail, the light gleaming from his iridescent feathers and yellow eyes, or the king vulture of the zoo treading sedately about with stiffly expanded wings.

In the breeding season, furthermore, many birds develop peculiar ornaments that add to the effectiveness of their display. The skin on the breast and throat of the male pectoral sandpiper at the opening of the mating season becomes full and loose so that it may be inflated to a grotesque, rounded swelling. Only on the breeding grounds in the northern tundras do these birds exhibit this development, and no one examining them as they migrate

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through the United States would suspect such a curious ornamentation. At this time, also, the male frigate birds, the larger species of which have a wing spread of six feet or more, develop a pouch on the throat that may be inflated at will to the size and appearance of a toy balloon. This sac, colored a brilliant cherry-red, undulates slowly from side to side when the bird is flying. The male frequently rests on his nest of coarse sticks, and as females come flying overhead he throws back his head, allowing the brilliant throat sac to roll from side to side while he utters a mellow whistle. As soon as the single egg is laid the male assumes his share of the tasks of incubation, and under the influence of these soberer duties loses his brilliant ornamentation. The sac becomes a dull orange and shrinks until it is hardly noticeable.

Every year is leap year for the Wilson's phalaropes—small, snipelike birds most common in the West—as well as for two related species of the same family. The female is much brighter and larger than the male (see frontispiece), and she plays the ardent lover to her duller, plainer mate, who flees in mock modesty, but finally capitulates. After the nuptials, also, he dutifully incubates the handsome eggs deposited by his stronger spouse, who flocks off with others of her sex, free from all thought of assisting in the care of her young.

The majority of birds are monogamous; but generally mating is only temporary, and male and female separate after the young no longer require parental care. Much still remains to be learned of the association of birds in pairs. Study of the house wren by the banding method has revealed that on occasion a new mate is taken for the second brood, or a male may forsake one mate after the eggs have been deposited and start another family with a new wife. On the other hand, cardinals and white-breasted nuthatches may remain mated throughout the year. In fact, the latter species is almost invariably found in pairs at all seasons.



Costa Rican tanager (*Chlorophonia callophrys*), above, and lovely cotinga (*Cotinga amabilis*), below, shown against a forest background in Costa Rica

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Numerous species, particularly among the gallinaceous birds, practice polygamy. Our common bobwhite, however, takes only a single mate. The turkey is an excellent example of a polygamous species, as is the prairie chicken, the male of which booms from a regular spot and mates with the females that come to him. Polyandry, too, is charged against a number of species of birds; but this charge needs verification, since our cowbird, the form most commonly accused of this practice, is found frequently in regularly mated pairs.

The nests of birds vary greatly in form and complexity. The simplest kinds are mere hollows in the earth, such as the shallow excavations that the common, least, and sooty terns, the black skimmer (Plate 27), and the blue-faced booby (see Plate 42) make to hold their treasures, or the slight depression in dead leaves chosen by the whippoorwill for its eggs. These nests contain no padding of any kind. The wedge-tailed shearwaters (Plate 29) dig a tunnel in loose soil, at the end of which the female lays her single egg; and as these birds often nest in great colonies their burrows may so honeycomb the soil that when one walks through their rookeries the apparently firm earth may give way beneath one's feet. The noddy tern, when nesting on rocky ledges or on the ground, often decorates the chosen hollow with a pebble or two, a feather, or possibly a bone. In wooded localities it builds a fairly substantial nest of twigs in a tree. The fairy tern, a small species of pure-white plumage that ranges throughout many tropical islands and hovers overhead as one enters its haunts, chooses the most precarious sites for its nest. If a tree is accessible the female deposits her single egg in some little depression on a branch that may not be more than an inch and a half or two inches in diameter. She herself then rests in front of the egg, holding it in position by throwing the feathers of her breast around it. In lieu of a tree the fairy tern will select a ledge of rock, on which it would seem almost impossible for the egg to

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remain in place. The young terns when hatched possess strong, prehensile toes, with which from the moment of birth they cling with tenacious grip to their insecure perches and so live to reach maturity.

The American avocet, a wading bird related to the sandpipers, deposits its eggs in a little hollow lined with a few bits of grass or weed stems in marshy ground. Rising waters frequently encroach on the breeding grounds, and then the birds rush about gathering weeds, grass, feathers, sticks, and even bones, with which they build their nests higher, elevating the eggs as they proceed, to keep them above the rising flood. Sometimes these nests reach a height of twelve or fifteen inches, so that as the flood waters subside the incubating birds, that normally would rest on the ground, are left at a considerable elevation.

The type of nest usual to our smaller birds is a cup-shaped basket, made externally of coarse materials and lined with finer stuff on which rest the eggs (see Plate 39). The depth of the nest is generally sufficient to insure security to the eggs, and the structure is firmly fastened to twigs and branches. Many ground-nesting species select little hollows which they line with an excellently made nest similar to the type just described.

Hérons, which in wooded areas nest in trees, build a loose structure of sticks (Plate 30), through which the eggs may often be seen from beneath. In extensive treeless marshes they build on clumps of rushes above the water or ground. The American and least bitterns (Plate 31) and the rails always nest in marsh growths, and the latter elevate their nests slightly above the mud and water (see Plate 43). The mourning dove is another species that builds a structure of twigs so flimsy and flat that we wonder how the two eggs can remain safely on its surface (see Plate 23).

Humming birds construct their nests of plant downs and soft fibers, bind them together with spider webbing, and cover them with bits of moss and lichen so that they



Pair of wedge-tailed shearwaters (*Thyellodroma tinnata*) at entrance of nesting burrow.
Lisianski Island, Hawaiian Bird Reservation. Photograph by Alexander Wetmore. Courtesy of the
Bureau of Biological Survey



Little blue heron (*Florida c. caerulea*) with nest and young. Photograph by Dr. Arthur A. Allen



The least bittern (*Ixobrychus e. exilis*) simulates its background of reeds by pointing its bill up and presenting its streaked breast to the observer. Photograph by Dr. Frank N. Wilson



Blue-headed vireo (*Vireo s. solitarius*) and its nest, suspended in the fork of a small limb. The fearlessness of the incubating bird is indicated by the hand at the right. Photograph by Dr. Arthur A. Allen

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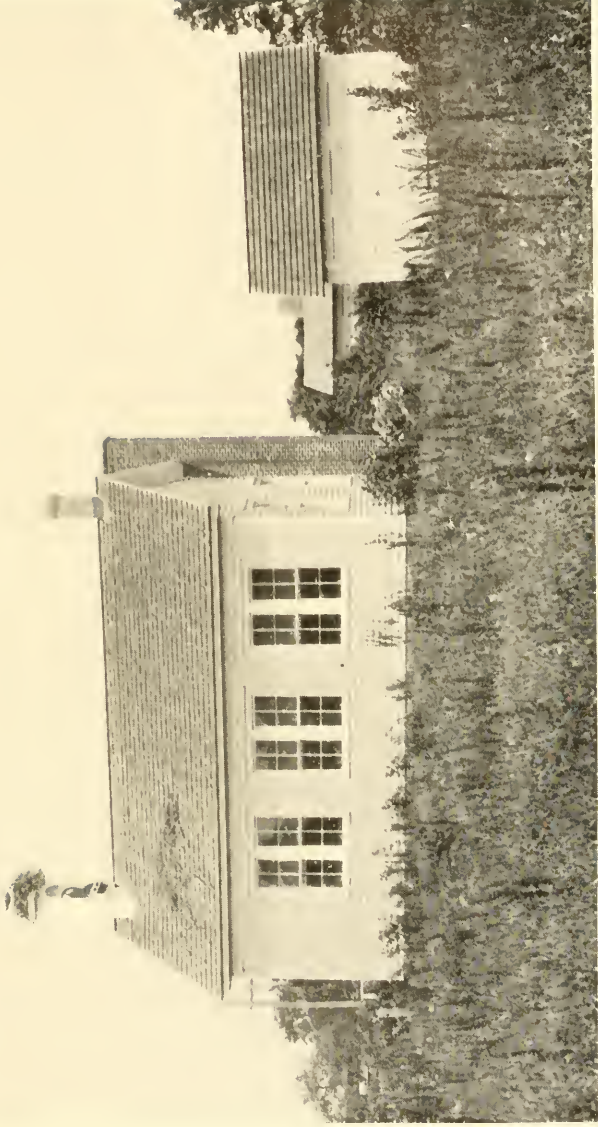
resemble closely the limb on which they are saddled. The vireos suspend a cup-shaped basket from the terminal fork of some slender limb, where it is firmly fastened and usually concealed among leaves (Plate 32). The Baltimore oriole goes a step further and weaves a purse or pouch of fibrous materials, which, though fastened tightly, hangs on slender twigs, swaying freely with the breeze. The Porto Rican and Haitian orioles weave a small basketlike structure beneath the stem of a palm leaf, puncturing holes through the leaf itself, to which they sew the nest by means of strong fibers. The Wagler's oropendola, of the same family as these orioles, whose nesting habits are described by Dr. Frank M. Chapman, weaves a pendent bag from twenty-two to forty inches in length, with the opening at the top and a somewhat narrowed neck that leads into the enlarged nest bag below. This species builds colonies of these bags in the tops of trees.

The nests of the fish hawk or osprey, a large hawk that captures fish by plunging from the air and seizing them with its rough, strong feet, are remarkable structures built of sticks in the tops of trees. The birds use the same nests continuously season after season, adding more material to them each year until they become enormous masses six or eight feet in diameter containing nearly a cartload of material. Often they increase in size until they break down the trees in which they are built. The farmers near Cape May, New Jersey, consider the fish hawk a desirable neighbor, because while harmless itself it is believed to drive other hawks away and so protect their hen yards from depredation. For this reason countrymen frequently place a wagon wheel, secured by its hub, at the top of a tall pole so as to form a platform on which the bird may make its nest. Fish hawks readily nest on such platforms. Occasionally a pair may even nest on a building (Plate 33), a curious adaptation in a bird of this type to modern conditions.

The ovenbird of North America, a species of wood

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warbler, builds on the ground, ingeniously constructing a nest of leaves, arching it over at the top and leaving a small entrance at the side somewhat suggestive of an old-fashioned outdoor oven (Plate 34). The nest is inconspicuous, as it is placed in wooded land, usually among undergrowth and well concealed. Far more remarkable is the nest made by the *hornero*, or ovenbird of South America, which belongs to a family (Furnariidae) peculiar to South and Central America. This bird's nest is as large as a man's head, constructed of mud, with walls more than an inch thick and an arched top (Plate 35). The opening is at one side and a passage leads to the back of the structure before the nest cavity proper is reached. In Argentina and Uruguay these strange, domed nests attract the attention of the least observant passer-by, as they are built without the slightest attempt at concealment. Though usually placed on more or less horizontal tree limbs, the nests appear on many other sites, such as the cross arms of telegraph poles, the slightly inclined trunks of palm trees, or the faces of clay banks. I have seen dozens of these structures set like capstones on the tops of fence posts or telegraph poles; and on one occasion I saw a nest of the ovenbird at each end of a house with a gable roof, placed as symmetrically as though done by human hands. The thick mud walls serve as protection to the eggs and young against hawks and other marauders. Some of the nests have the entrance at the right side and some have it at the left, almost as though certain of these birds, like certain people, were right-handed and others left-handed. Numerous relatives of the ovenbird, like the *leñatero* (a Spanish word meaning fagot-gatherer) build large structures of thorny twigs interlaced to form a rounded mass, within which they place the nest proper. The edifice protects the egg from most enemies and is so durably constructed that it may last for several years, so that these nests are prominent features in the trees in many parts of South America.



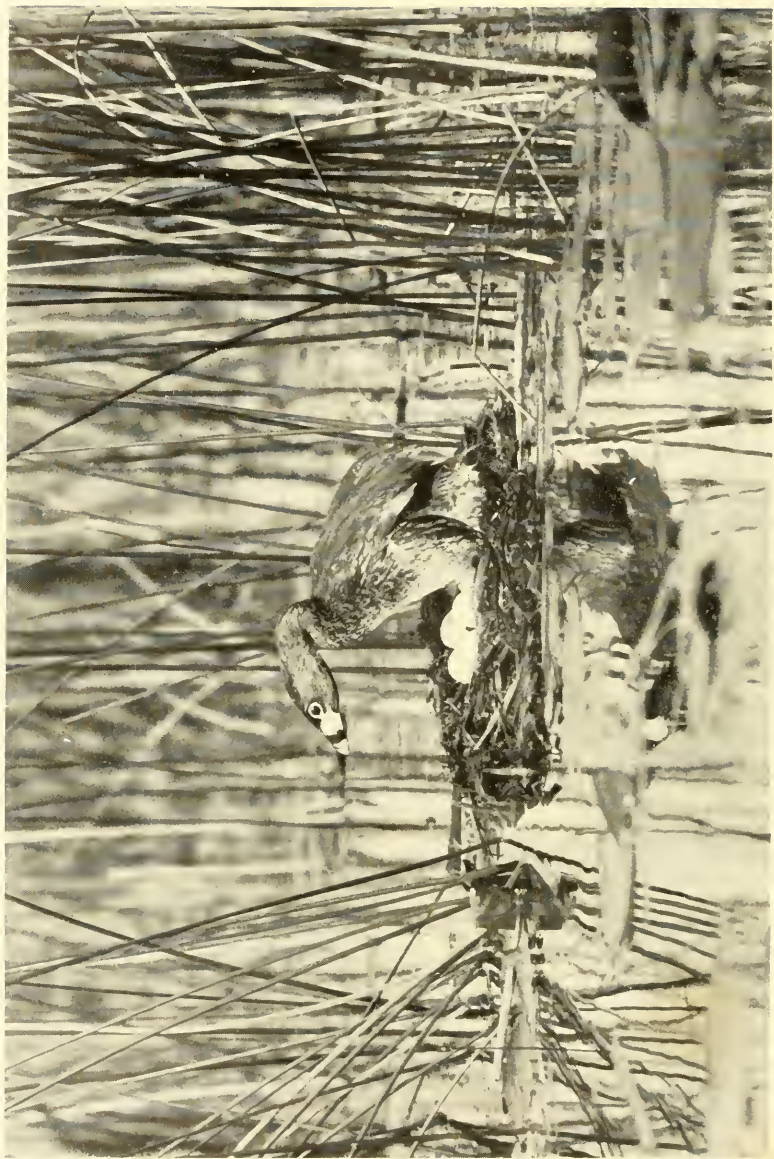
Nest of osprey (*Pandion haliaëtus carolinensis*) on belfry of country schoolhouse near Cape May, New Jersey. Photograph by Alexander Wetmore



Ovenbird (*Seiurus a. aurocapillus*), a wood warbler that lives on the ground and derives its name from its domed nest, shaped like an outdoor oven. Photograph by Dr. Frank N. Wilson



Domed nests of the ovenbird (*Furnarius r. rufus*) of Argentina and Uruguay. These mud nests are built commonly on the roofs of houses, on the limbs of trees, or on poles. Photograph by Alexander Wetmore. Courtesy of the Bureau of Biological Survey



Pied-billed grebe (*Podilymbis p. podiceps*) with its nest, composed of floating vegetation. Photograph by Dr. Frank N. Wilson

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Woodpeckers nest in holes that they cut in trees with their chisel-like bills. Usually they select dead trunks in which they chisel a round opening and then excavate the nest cavity to a suitable depth. There is no nest lining other than a few chips of wood. Some species cut into the trunks of living trees; the common woodpecker of Haiti and the Dominican Republic, which nests in palms, and the sapsuckers of the United States frequently do so. The red-shafted flicker of our Western States, in regions where trees are scarce, makes tunnels in the faces of banks of earth, just as a kingfisher does.

Barn and cliff swallows mold pellets of mud into firm cups to serve as nests, and the latter species completely incloses them except for an elongated tunnel or bottle-neck entrance. The tree and violet-green swallows select old woodpecker holes which they line with grasses and soft feathers to receive their eggs, while the bank and rough-winged swallows excavate tunnels in earthen banks. The latter species also sometimes utilizes cavities in masonry or drains in walls. The nuthatches of North America make use of holes in trees for nesting; but the rock nuthatch, which ranges from southeastern Europe to Palestine, in Asia Minor, prepares its nest in a rock cavity by closing it in with mud, or even makes a retort-shaped structure of mud to contain its eggs.

A group of small swifts native to India, Australia, and the islands of the South Pacific build on the walls of caves cupped platforms of a coagulated mucus secreted by the glands of the mouth. In a number of localities these mucus nests are gathered each season and sold for use in a soup relished by the Chinese. The chimney swift of North America builds its nest of small dead twigs broken from the limbs of trees as the bird passes in flight. These are cemented together by the mouth secretions to form a little basket, which in early times was placed in the hollow of a tree, but which now is usually found on the inside wall of a chimney.

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The diving grebes, which are wholly aquatic in habit, build up masses of weeds and rushes in shallows until a platform appears above the water, and on this they deposit their eggs. When the mother leaves the nest she covers the eggs with the nest material, so that the mound resembles a heap of rubbish and attracts no special attention (Plate 36). Most ducks nest on the ground, the mother bird lining the nest warmly with down plucked from her breast (Plate 40).

Many weaver finches are gregarious in their nesting, building in colonies in the tops of trees, a number of species making baglike structures like those of orioles. Dr. Herbert Friedmann, studying their habits in captivity, has found that some species of these finches well merit the name "weaver," as they twist their nesting threads ingeniously into loops and hitches that hold to perfection. Nests of other weavers may be untidy gatherings of straws and weeds with ends projecting at random. Most remarkable are the homes made by the social weavers, a company of which will together assemble a great mass of grass in a tree to form a common roof, beneath which each pair has its separate nest lined warmly with feathers. From twenty to three hundred pairs may share a single roof, which is often used year after year and grows in size until it may contain several wagonloads of material. Presumably the custom of communal nesting has arisen from the habit of constructing ordinary covered nests in colonies. When, finally, the nests came to be so closely placed as to touch, the birds developed the habit of uniting them into one mass. The palm-chats of Haiti and the Dominican Republic, relatives of the waxwings, also construct a communal nest of dead twigs, usually around the crown of a palm, with a separate section reserved for each pair. The sticks used may measure from ten to thirty inches in length and equal a lead pencil in diameter, so that we wonder how birds no larger than a bluebird can bear them aloft thirty to fifty feet to the nest.

CHAPTER VII

EGGS AND THEIR CARE

It is almost unnecessary to state that all birds hatch from eggs which have been subjected, in a nest of some kind, to a fairly uniform heat during a period of incubation. This process develops the embryo to the point where it breaks the shell.

The eggs of a majority of birds are oval in shape, rather bluntly rounded at one end and somewhat pointed at the other. Sandpipers and plovers lay very pointed eggs, probably to enable the mother to accommodate the set beneath her breast, as the eggs are relatively large and usually number three or four. By arranging them with the points toward the center they occupy a minimum space, so that they may be covered and successfully incubated. Eggs of murrets and of other species that lay a single egg on the rocky ledge of a cliff are also very pointed at the small end, an arrangement which is supposed to represent an adaptation for safety. The eggs are laid on the bare rock, without nesting material of any kind, and because they are markedly pointed they roll in a circle of small diameter when disturbed, which lessens the chance of their going to destruction over the side of the ledge. The eggs of swifts are nearly elliptical and those of owls nearly round.

The egg consists at first of the yolk, or yellow, which is the part formed in the ovary and which carries the embryo. Then come successively, surrounding the yolk, the white, or albumen, the shell membrane, and the calcareous shell, deposited in the order named as the egg passes

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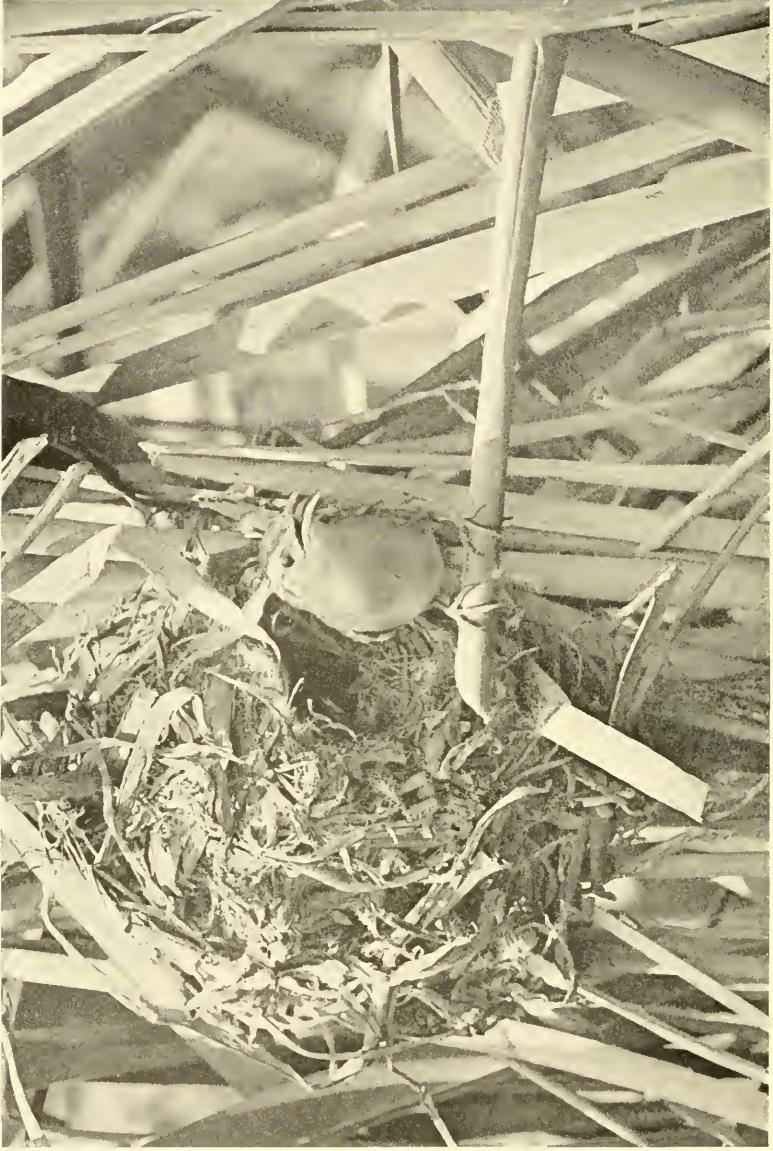
through the oviduct. The shell is soft when formed but hardens rapidly and in most eggs is firm and strong before the egg is deposited in the nest. The only exceptions are the eggshells of some pelicans and penguins, which when first deposited are said to be flexible, although they, too, harden to a firm texture immediately afterward.

The domestic fowl not uncommonly lays eggs with double yolks, a formation due to the liberation of two yolks from the ovary within a relatively short time, so that both pass down the oviduct together and become inclosed in one shell. Very rarely, eggs with three yolks in one shell have been found. In a period of six years Maynie R. Curtis obtained three eggs of this type from about three thousand fowls. Each of the three was the first egg produced by a young pullet. Another abnormality occasionally observed in hen's eggs is that of an egg within an egg, due seemingly to the abnormal, enforced return up the oviduct of an egg that has been inclosed in a shell, so that as it passes down the oviduct again a second layer each of albumen, shell membrane, and shell is formed around the original shell.

The shells of small eggs appear smooth and even, but examination under a microscope reveals them to be penetrated by pores. These are the openings of little canals through which a slow exchange of gases between the interior of the egg and the outer air is possible. The pores in larger eggs can be seen on careful examination by the naked eye, while those in the eggs of such species as the ostrich occur in slight depressions and form a prominent feature of the egg. The arrangement, abundance, size, and shape of these pits and pores differ in different groups of birds, so that these characters are sometimes useful in distinguishing the orders and families to which eggs belong. The eggs of the California condor, which are very large, unmarked, and tinged a very pale greenish-blue, are so scarce that collectors now value them at \$750 each in making exchanges of specimens. Unscrupulous



Loon (*Gavia immer*) on its nest, built on a point of land. Photograph by Dr. Frank N. Wilson



Long-billed marsh wren (*Telmatodytes palustris*) and its ball-shaped nest. This species inhabits marshes.
Photograph by Dr. Frank N. Wilson

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persons attempt occasionally to palm off goose eggs of the proper size and color for the eggs of condors, but the true identity of such spurious eggs may be determined by examining the shell structure.

The eggshells of some birds, for example woodpeckers, have a distinct gloss, the white eggs appearing smooth and hard. The tinamous—a group of New World birds, ranging from Mexico to Patagonia, which resemble partridges and quail in general appearance but which in reality are primitive forms related to the rhea and the ostrich—have eggs with a highly polished surface, like the hardest and smoothest of porcelain. This character, coupled with their handsome tints of pink, pale-blue, or brown, according to the species, places them among the most remarkable eggs known. The three-toed tinamou of Patagonia (*Tinamotis ingoufi*) whose egg is dull green with a very rough shell, seems to be the only member of the family that does not have a glossy egg.

The emu of Australia, a large ostrichlike bird, has a dark-green egg with a roughened, irregular surface. The egg of the chachalaca, a pheasantlike bird living principally in trees in tropical America (although one species comes north into the lower Rio Grande Valley in Texas), is distinctly corrugated so that two of the eggs when rubbed together produce a grating sound.

Though the eggshells of most kinds of birds are clean and smooth, those of boobies, cormorants, anis (or witch birds), and some other species have heavy, chalky deposits of calcareous matter on the outer surface. The witch bird's egg is particularly beautiful because the green surface is penciled like a mosaic with irregular pure-white lines. The eggs of ducks frequently have an oily surface that may protect them against undue moisture.

The colors and markings of eggs have infinite variety and constitute the main attraction of the study of oology. The eggs of most birds that nest in holes or have their eggs placed under cover are pure white without colored

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markings. This is true of the eggs of woodpeckers, swifts, and owls and of those of the many species belonging to the group known as the tracheophones—peculiar perching birds of South America. Because reptiles, which precede birds in the evolutionary scale, have white, unmarked eggs we suppose that a white egg in birds is indicative of the most primitive type of the class. Those species laying white eggs exhibit, therefore, a primitive character.

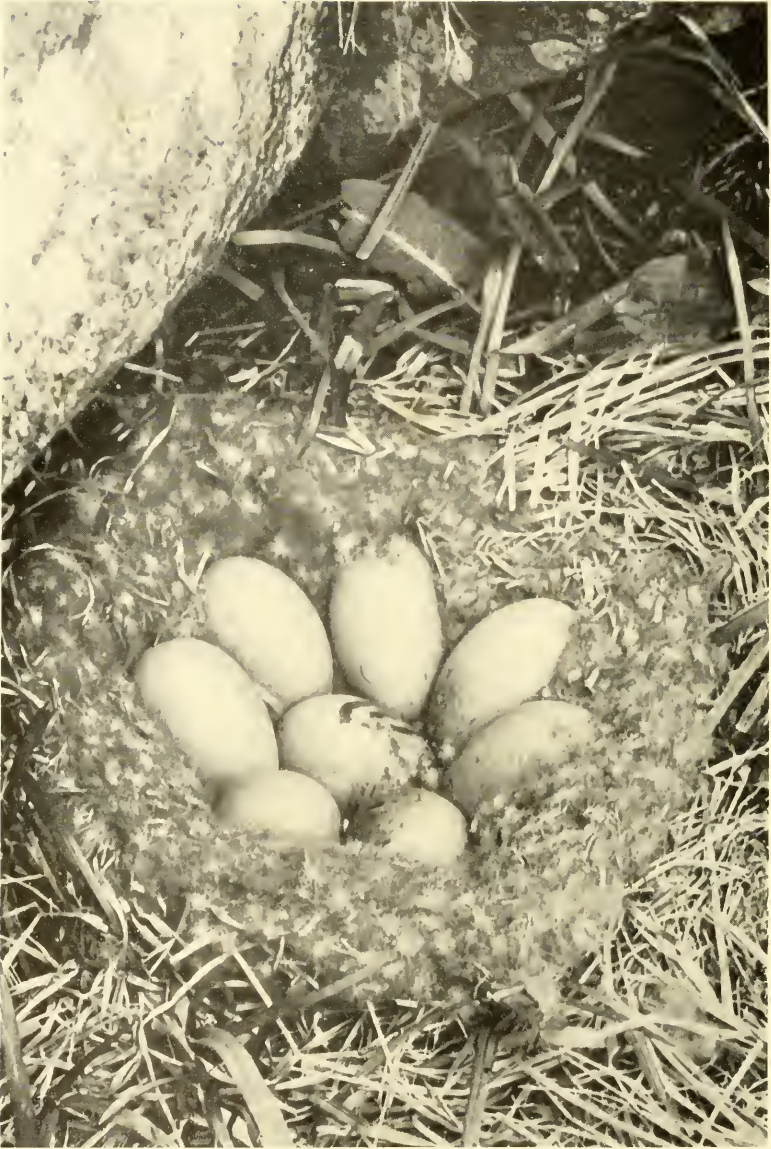
In some species of birds pigment occurs throughout the calcareous material of the eggshell, so that the egg is tinted instead of pure white. The brown, pink, or blue eggs of the tinamous, already mentioned, and the buff egg of the ruffed grouse are examples of this. The eggs of the different varieties of domestic fowl, ordinarily plain and unmarked, show considerable variation in tint from white to brown. The white leghorn's egg is white, the barred plymouth rock's is brown, and the Flemish or Dutch fowl's very deep brown. Occasionally a light-colored egg shows a few spottings of brown. Along the west coast of South America from Peru to Chile there occurs a strain of domestic fowl, sometimes called the Araucanian, in which the eggshell is tinted distinctly blue. The characteristic of blue eggs seems to be a dominant one in this strain, for it is common to fowls of much variety of appearance. An Araucanian hen in the National Zoological Park, although she resembles any nondescript barnyard fowl in appearance, lays eggs heavily tinted with blue.

The white or tinted eggs of many species of birds are spotted with a deeper color (see Plate 27). These markings vary from a few scattered dots, as in the white eggs of the red-eyed vireo spotted sparingly with blackish and deep brown, to a suffusion of spots covering the entire surface, as in the eggs of the sparrow hawk. Species that normally lay a pure-white egg, as the phoebe, often vary this with a pattern of minute dots of deep brown on a white ground.

Where an egg has colored markings of any kind they



Kingbird (*Tyrannus tyrannus*), a common flycatcher of eastern North America, on its nest. Photograph by Dr. Frank N. Wilson



Nest and eggs of eider duck (*Somateria dresseri*), surrounded by soft down plucked from the mother's breast. The nest material is gathered to form the eider down of commerce. Photograph by Dr. Arthur A. Allen

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tend to form a ring or wreath about the larger end. This results from the fact that the egg normally travels down the oviduct with the large end ahead, so that this end is the first to come in contact with the coloring matter and may absorb most of it and exhaust the supply. The eggs of both the sparrow and duck hawks regularly exhibit such wreaths. In addition to the suffusion of spots that obscures the ground color, these eggs are marked also with heavy, overlying spots of a deeper tone. Not infrequently the wreath of colored markings appears at the small end of the egg, due, it is believed, to some accident which reverses the egg, so that it travels down the oviduct small end first.

Colored eggs offer an endless variety of markings. Those of loons (Plate 37) are deep brown, with somewhat obscure touches of deeper brown. The background of the sooty tern's eggs varies from nearly white to a reddish tint, and the eggs may be very lightly spotted or blotched with heavy masses of color that obscure much of the ground color. As these birds nest in large colonies, several thousand pairs often collecting in an area of a few hundred yards, one has the opportunity to examine countless specimens and marvel at the great variation in color in the individual eggs. Seemingly no two are identical.

The eggs of our common species of sparrows are usually spotted with brown or lilac on a white to pale-green background. There are occasional exceptions, as the dickcissel, a bird as large as a house sparrow with a black necktie and bright-brown shoulders, which lays a pale-blue egg without markings. The eggs of most of the wood warblers, too, are spotted, but that of Swainson's warbler is very faintly bluish white without markings. The egg of the Baltimore oriole is white with many fine lines of black or blackish brown scrawled over the surface as though by a pen held in a careless hand, the form and shape of these lines indicating that the egg was rotating irregularly in the oviduct at the point where the color was applied. The eggs of the crested flycatcher are

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creamy white with prominent, very straight, longitudinal streaks of chocolate, which seems to indicate that, though the egg was traveling along the oviduct while the color was being applied, it did not rotate.

Though the majority of birds whose nests are in holes or under cover lay pure-white eggs, not all do, as brown creepers, nuthatches, and chickadees build always under cover and always lay spotted eggs. There are a number of curious anomalies in this respect, however, among species apparently closely allied. For example, the short-billed and the long-billed marsh wren both make ball-shaped nests with an opening in the side (Plate 38), the eggs being completely hidden; but the former lays pure-white eggs, rarely faintly spotted with lavender, while the eggs of the latter are normally so finely and uniformly dotted with dark brown as to appear almost solid chocolate in color. The cliff swallow, which builds a covered nest, lays a white egg spotted with brown; while the bank and rough-winged swallows, laying in nests built at the end of tunnels dug in banks of earth, have pure-white eggs, as does the tree swallow, which nests in holes in trees.

Spectrum analysis of egg colors has indicated that there are seven pigments involved. The commonest of these is known as oorhodeine, which has a peculiar red-brown tint. Two other pigments when pure are bright blue, two are bright yellow or reddish yellow, and the remaining two are but indefinitely known. These pigments, in varying combinations, produce all the colors found in eggs.

Mr. P. Bunyard has shown by inserting a tiny electric-light bulb in eggshells that the grays and mauves evident in many eggs are actually the same color and the same pigments as the darker markings, covered by a film of calcareous matter which allows the color to show through but changes its appearance from blackish or brown to lilac. In some shells the modification produced by the calcareous deposit is remarkable. Certain eggs of the razor-billed auk, for example, externally appeared to be merely suf-



The Fijian lory (*Phigys solitarius*), above, and orange dove (*Chrysoena victor*), below, of the forests of Taveuni, in the Fiji Islands

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fused with grayish markings, but internal illumination showed broad patches of dark pigment. The superficial color characteristics of many eggs almost entirely disappear when illuminated internally. This method of examination often revealed fractures in the shell surface, made apparently when the egg was in the oviduct but which had healed before the egg was laid, leaving no external evidence of their occurrence.

Abnormalities among birds' eggs are not infrequently due to some injury to the female while they are being formed, but improper formation accounts for most. The commonest is the so-called runt egg, one appreciably smaller than normal. The delight of a child in the novelty of the occasional small egg from the domestic hen yard is almost equaled by that of the collector of birds' eggs in the rare examples of these dwarf eggs found in the nests of wild birds. Occasionally runt eggs are due to a yolk smaller than normal; at other times they result when some bit of membrane, tissue, or possibly a parasite accidentally passes down the oviduct and is covered with albumen, shell membrane, and shell like a normal yolk. At times these dwarf eggs are formed around masses of albumen without any yolk whatever. In large series of eggs of any kind they are not infrequent.

The largest eggs known are those of the extinct *Aepyornis* of Madagascar, sometimes called the elephant bird. Its eggs are found in sand dunes, fragments being very abundant in some regions, while a good many complete specimens have come to light. The eggs sometimes measure a little more than thirteen inches in length and nine and a half inches in diameter and hold more than two gallons of fluid. The shells of some are smooth, but pitted as is the shell of an ostrich egg, while others are considerably roughened. The dimensions of an *Aepyornis* egg may be contrasted with those of the egg (a quarter of an inch long) laid by the vervain hummers of Jamaica and Haiti, among the smallest species of humming birds.

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The size of the egg in relation to the size of body of the parent bird varies considerably. The larger species of kiwi or apteryx of New Zealand weigh approximately four pounds and so equal in bulk the larger varieties of the domestic fowl, but their eggs are several times as bulky as hen's eggs. They weigh fourteen to fifteen ounces and measure four and three-quarters to five inches in length and two to three inches in breadth.

The number of eggs produced annually by different kinds of birds varies among the different species and is governed normally, of course, by the requirements for maintenance of each form. The migratory species that perform extensive journeys and thus encounter many dangers require a higher rate of annual egg production than sedentary birds. Thus, on the average, the small birds of the temperate zones that migrate annually produce more young each year than the small birds of tropical and subtropical zones that remain in a comparatively restricted range. The mortality among the former increases with the extent of the migration journeys. Most small perching birds in temperate regions lay from three to five eggs, rarely six, at a setting and may produce two or three broods during the season. Many tropical species of the same groups produce only two, three, or sometimes four eggs at a setting and may nest only once each year. The song sparrow of the temperate zone frequently has three broods a year averaging four young each, and thus one family at the close of the season may have a maximum of twelve young and two adult members, or fourteen in all. This permits the destruction of twelve individuals before the next breeding season without annihilating the family, for at least one pair must survive to hold this particular family group in existence.

The number of eggs laid by a small species of perching bird under tropical conditions is well illustrated by the little sparrow known as the Carib grassquit, or parson bird of the West Indies. Mr. B. S. Bowdish has records

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of twenty-seven complete settings of this species in Porto Rico. Two of these settings contained two eggs, twenty contained three eggs, two contained four eggs, and three contained five eggs, making an average of three and one-fifth eggs to a setting. The species is very abundant, indicating that the reproductive quotient is high for a resident form of bird. Most of the migratory sandpipers and plovers lay but four eggs to a setting and rear only one family each year; some species of this group lay only three eggs to a setting. Though this rate of reproduction sufficed to maintain the sandpipers and plovers under ordinary conditions, when man began to hunt them systematically they decreased rapidly in numbers, and they have had to be put on the protected list in the United States and Canada to prevent their extermination. There is little doubt but that further protection will need to be given the woodcock, which is still legally hunted, if its apparent decrease in abundance is to be checked. Wild ducks, because they lay from five to twelve eggs at a setting, have a better chance for survival in spite of the large number that are killed annually. The passenger pigeon, tremendously abundant in the early days of our country, laid only one egg at a setting, and as it congregated in great colonies to nest, was subjected to a destruction by hunters so overwhelming that it could not maintain itself and became extinct. The great auk, a flightless species, also laying only one egg, congregated on small islands, where sailors and fishermen killed the birds to provision their ships, so that the species was exterminated in a relatively few years after transatlantic voyages became common.

After the full set of eggs of any bird is laid, a period of incubation begins, during which the eggs are subjected more or less continuously to a uniform temperature that enables the fertilized ovum to develop to the point of hatching. In the ordinary method of incubation one of the parent birds remains on the nest, covering the eggs continuously except for the brief intervals needed for a

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hasty search for food. Close contact with the breast and abdomen of the brooding bird warms the eggs; an increase in the blood supply to these parts produces a thickening of the skin; and the down and other small feathers over this area slough off to allow close contact between the body of the parent and the eggs, thus bringing an even degree of heat to bear on them. The bare areas of skin in contact with the eggs are known as incubation patches and vary somewhat in form in different groups. In the perching birds the entire region of the female's abdomen and lower breast becomes bare. The king penguin holds its single egg on its feet in a fold of skin on the lower abdomen, which is bare of feathers. Most shore birds have an incubation patch on either side of the abdomen, while that of the sooty and fairy terns is near the center of the lower surface of the body and is just large enough to cover the single egg laid by these species.

The exact degree of heat required to develop the embryo in the egg is at present accurately known for only a few kinds of birds. In the artificial hatching of the domestic fowl's eggs the incubator is maintained at an average heat of 103° Fahrenheit. Charts prepared by Baldwin and Kendeigh giving data obtained by means of a thermocouple (a wire composed of two joined metals extremely sensitive to change in heat) introduced in the nest, show the incubating temperature of the house wren's egg to vary from 102° to 106° Fahrenheit, the average being about 104° .

Though the care of eggs in incubation usually consists in keeping them warm by contact with the body of the parent, species of birds nesting in the open in regions where the sun's rays are very hot may be required to shade the egg from injury. In such cases the bird often stands above the nest merely to interrupt the direct rays of the sun. Many herons are required to do this in the middle of the day, although at night they may have to cover the eggs closely to preserve their warmth.



Blue-faced booby (*Sula dactylatra*) at nest, Lisianski Island, Hawaiian Bird Reservation. Photograph by Alexander Wetmore. Courtesy of the Bureau of Biological Survey



Virginia rail (*Rallus virginianus*) and nest, built in a clump of rushes elevated a few inches above the mud and water of its swampy haunt.
Photograph by Dr. Arthur A. Allen

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Ordinarily the female assumes the duties of incubation, but in many species, including the ostriches, a number of kinds of auklets, and some of the petrels, both sexes share this task. The male rose-breasted grosbeak broods devotedly, though this would seem a risk to the species because of his striking black-and-white coloring with a brilliant spot of rose-red on his breast that often shows above the rim of the nest. His mate, on the other hand, has an inconspicuous, streaked dress of brown. The male alone of the phalaropes, the bustard quails, the emu, and the rhea, cares for the eggs, the female taking no share in their incubation after the complete set has been deposited.

The megapodes, known also as the mound birds, a curious group of gallinaceous birds whose species are distributed from the Nicobar Islands, in the Indian Ocean, south and east to the Philippines and Australia, carry on no direct incubation whatever. The scrub fowl, a member of this family that ranges in the Northern Territory and Queensland, Australia, rakes together with its strong feet during the wet season a mound of earth to which it adds a small amount of vegetation. A single mating pair bury their eggs in the top of the mound, where they are said to be held at an incubation heat of about 95° Fahrenheit, generated by decomposition of the damp vegetation. As the same nest site may be used season after season, the mound grows steadily in size, and specimens fourteen feet high and thirty-five feet in diameter have been described.

The mallee fowl (*Leipoa ocellata*), another Australian species, makes a similar nest by scratching out a hole in the ground two feet wide and a foot deep, and piles the excavated earth around the edge to form a raised rim. The bird then fills the cavity with leaves, twigs, and other vegetable débris, scraped together with wings and feet for yards around. It leaves the hole uncovered for several months to be soaked by the rains, and then rakes up sand and earth until the mound is twelve to eighteen feet in diameter (see Plates 57, 58 and 59). At the proper time

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the mallee fowl makes a depression in the top of the mound and mixes the vegetable débris taken therefrom with sand, replacing the mixture in the depression. A few days later a hole is dug in the prepared earth in which the female places an egg so that it rests upright with the small end down. The parent birds remain in close attendance; on clear days when the sun is shining they make a cavity in the sand above the egg to catch the warming rays, and in damp, rainy weather they cover the conical peak of the mound with sticks and rubbish that form a thatch to turn aside water which would otherwise penetrate the earth and chill the egg. By this artificial means the egg is incubated at a temperature ranging from 90° to 100° Fahrenheit. It is said that in dry, rainless seasons the mallee fowls do not breed. On the whole the nesting activities of these curious birds are strongly suggestive of those of some of the reptiles.

The length of the incubation period varies greatly in different groups of birds, generally being longer in the larger species, and shorter in the smaller ones. The period for different nests of the same species may vary slightly, due to differences in the total amount of incubation heat caused by relative irregularity in attention on the part of a parent; but on the whole the periods for the individual species remain quite constant. The eggs of the emu are said to require from fifty-six to sixty-three days of incubation, those of the ostrich forty-two days, of the domestic mallard twenty-eight days, and of the domestic fowl twenty-one days. The eggs of most smaller perching birds, like the finches, warblers and vireos, require twelve to fifteen days, while those of larger species, such as magpies and jays, take sixteen to eighteen days. The shortest period of incubation known is ten and a half days, required by eggs of the cowbird of North America, a species parasitic in its breeding. The cowbird builds no nest of its own but lays its eggs in the nests of other small birds, who hatch and rear the young cowbirds.

CHAPTER VIII

SOMETHING ABOUT YOUNG BIRDS

THE young bird when fully developed in the egg gains entry into the open air with the aid of a little point, called the egg tooth, on the end of the upper half of the bill. During the later days of incubation this point rubs around the inside of the shell as the egg is turned, and cuts the membrane and the shell. The completely developed embryo bird lies folded compactly within the egg with the head bent to one side. At the proper time a convulsive movement that tends to straighten out the neck thrusts the end of the bill through the membrane closing off the air chamber at the large end of the egg, and the first air enters the lungs of the bird. Animated by this, it begins to knock the egg tooth against the shell until a hole forms and more air is let in. The end of the egg finally cracks off and the bird emerges gradually as it gains strength and bulk from the inhalation of air. As the eggshell dries after the young bird has quit it, the shell membrane contracts and tends to pull the broken margin in all around, giving the shell the appearance of having been opened by the parent from without. This is misleading, however, as the young bird within the egg does all the work of liberation.

Birds are hatched at one of two general stages of development according to the species. The first is an advanced stage in which the eyes and muscles function strongly as soon as circulation has aerated the blood, and the bird is active from birth. Birds in this stage, including the young of chickens, quail, and ostriches, are called precocial. They leave the nest within a few hours after

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hatching and follow the parent in search of food (Plate 44). Species with precocial young usually leave the empty eggshells in the nest. The other stage of development at hatching is a much less advanced one. The bird is weak and undeveloped, its eyes are closed, and it lives for several days or weeks in the nest before launching into the world. Young birds hatched in this stage are called altricial and include parrots (see Plate 69), sparrows (see Plate 25), warblers, hawks (Plate 45), owls, kingfishers (Plate 46), and others. The parent birds of these species remove the empty eggshells soon after the young hatch and carry them to a distance before dropping them, a wise precaution to avoid calling attention to the nest.

The newly hatched bird weighs about two-thirds as much as did the freshly laid egg from which it developed. The loss in weight is due, in part, to escape of gases through the pores of the shell—gases formed as a result of chemical changes which take place when the yolk and albumen are transformed into the body of the embryo—and in part to the discarding of the shell and its membrane. Precocial young, which are active immediately on hatching, necessarily reach a more advanced stage of development within the egg, a development which is aided by the greater proportion of yolk or stored food in the egg. This averages from one-fifth to one-half the entire weight of the egg, according to the species. Altricial young, which are comparatively helpless when born, come from eggs in which the proportion of yolk is less, ranging from one-seventh to one-fourth of the total weight.

The young of the megapodes or mound builders attain the highest development before hatching of any birds known. We have said that the eggs of the mallee fowl, or leipoa, like those of others of the family, are buried in the nesting mound by the mother, who places each egg so that it stands upright with the small end down. In this position the embryo rests with the head up, so that on hatching

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the chick emerges in such a position that it naturally works upward and thus escapes from a burial which, carelessly arranged, might well prove a tomb. By convulsive scratching the young bird makes its way through the loose sand that covers it, often to a depth of many inches. When finally it appears above ground, it shakes itself briskly and gives a great gasp to fill its lungs with air. Almost immediately it runs instinctively to hide in the thick scrub that surrounds the nest mound. On hatching, the down that clothes the body is covered with a gelatinous substance, but this rubs off in the sand as the chick digs itself out. The wings already are sufficiently developed for flight, and although it prefers to run, the young mallee fowl can fly for a distance of ten or fifteen yards as soon as its wings are dry. The parent birds remain attentively about the mound throughout the period of incubation, keeping the earth at the top loose and making and closing openings above the eggs to regulate the temperature. However, when the young are hatching, the parents pay no attention to them but leave them entirely to their own devices. In a short time the fledglings have learned to secure food, and they gather in little flocks in the thick scrubs. At this stage in their existence the mallee fowl are subject to heavy toll from predatory animals, for although they fly, they alight always on the ground and, according to reports, do not begin to roost in trees until about half grown.

Precocial young of an entirely different type are found among the curious aquatic birds known as grebes, which live almost entirely on the water and come ashore only occasionally to rest or sleep in the sun. Even at such times they never venture more than a few feet from the water's edge. Grebes rake together masses of vegetable rubbish to make nests in shallow water, and the eggs are always damp from the moist bed in which they lie. Young grebes seem to leave the nest almost immediately on hatching, for I have found nests of the eared grebe con-

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taining shells in which the shell membrane was not yet dry, and yet the young were nowhere to be seen. The young follow the mother, clambering up on her back when tired, as on a raft. They are supported in this position by the feathers of the inner part of the mother's wing. On many occasions I have observed adult pied-billed and western grebes swimming about with the heads of their newly hatched young sticking out through the feathers of the back. Here they are kept warm and dry and are hovered as efficiently as a mother hen hovers her chicks beneath her breast.

Young grebes are born with large heads, long necks, very slender bodies, greatly developed legs, and broadly lobed feet. They swim and dive readily, usually progressing with the forward part of the back completely submerged and only the head, neck and rump projecting above the surface. Adult grebes often dive with young on their backs, occasionally maintaining them in this position for a time as they swim under water, but ordinarily freeing them at once so that they come to the surface. The western grebe usually tries to gain the cover of rushes before diving so as to enable its young to hide.

The diving of young grebes is easily observed in clear water. Young pied-billed grebes are able to stay beneath the surface for a considerable period. In fleeing from an enemy they usually swim rapidly under water but occasionally hang suspended five or six inches below the surface, with beady eyes watching intently to determine the proper direction in which to escape. If placed on land, these newly hatched birds progress by a series of leaps made with both feet moving in unison and wings extended, and at each jump they fall forward on the breast. The motion duplicates exactly that used in swimming, and the birds show no ability to modify this for more effective progress on land.

The young of various species of ducks are fully covered with down when hatched and in the space of a few hours



Herring gull (*Larus argentatus smithsonianus*) standing over its nest, which contains two eggs and one downy young. The young are active and leave the nest soon after hatching. Photograph by Dr. Frank N. Wilson



Female marsh hawk (*Circus hudsonius*) and downy young. This species nests on the ground. Photograph by Dr. Frank N. Wilson

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are sufficiently strong to follow the mother into the water. The males among most ducks flock by themselves as soon as their mates begin to incubate the eggs, leaving the care of the young entirely to the mother, so that in such species as mallards, pintails, teals, and shovelers it is rare to see a brood of young accompanied by both parents. The ruddy duck forms an outstanding exception to this rule, for the male of this species remains attentive to his family throughout the period of incubation by the female and the subsequent period of growth in the young. At the proper season male ruddies can be seen swimming proudly, with spread tails and swelling chests, convoying their offspring among the rushes. Among the surface-feeding ducks, the mother and her brood ordinarily remain as a unit until the young are grown, the group feeding and resting in company. It is not unusual to find a young bird of some other species with such a family, but this is either some lost youngster that has attached itself to the group or possibly the product of a stray egg deposited in the nest by a stranger duck.

The redhead, a diving duck that nests in great numbers in the broad marshes of the Great Basin and elsewhere in the western part of North America, does not take later family cares too seriously, although she is an attentive mother during incubation. Young redheads are independent and fearless when only a few days old and seem to feel that they have little need for parental guidance. The wide world of water and rushes that spreads before them is attractive and seductive, and tempting foods and other diversions continually lead them aside. When ten days to two weeks old the majority forsake the mother; or the mother, disgusted with the lack of attention given her wise counsels by her too precocious children, forsakes her family. In any case, the young are thrown on their own resources; but in spite of their independent spirit they are very gregarious and remain in bands that sometimes grow to fifty or a hundred individuals. These flocks, large

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and small, move about through the marshes, individuals that become separated joining other bands and all traveling to find food and see the world. They have a tendency to move against water currents, so that they often travel upstream. The ducklings may even come up the irrigation ditches that border the streets of such towns as may be located near enough to the native marshes of the birds.

All young ducks when small rely upon diving and hiding to escape their enemies. In the young of the surface-feeding species, such as the mallards and teals, the wings develop at an early stage, and in a relatively short time after hatching the ducklings are able to fly. On the other hand, the diving ducks, like the redheads, canvasbacks, and bluebills, undergo extensive development of the legs in early life and become expert divers while still very young, able to stay long under water and thus travel concealed for considerable distances. Full growth of the wings in these divers comes only at a relatively later period in life.

The wood duck, in the Eastern States sometimes called the summer duck, makes its nest in a tree hollow located anywhere from three to fifty feet above the ground and sometimes overhanging water. The eggs number from six to twenty and are laid on rubbish found in the nesting hole, to which is added down from the breast of the mother. The eggs hatch in twenty-eight to thirty days. As soon as the young are dry and have become active, they scramble up to the nest opening and jump out, falling gently to the leaves and other vegetation below or to the welcoming water. The slight weight of their tiny bodies prevents any injury from the fall. When the brood has all assembled the mother leads them to water, if indeed they have not actually fallen there. Some observers state that they have seen the mother wood duck carrying the young to water in her bill, but this does not seem to be the usual method. The ducklings have very sharp claws with which they climb readily, a wise provision that enables them to leave the nesting cavity with ease. They climb



Young belted kingfishers (*Megascops a. alcyon*) about two weeks old, showing developing pin feathers. These birds nest in tunnels dug in steep-faced earthen banks. Photograph by Dr. Arthur A. Allen

PLATE 47



One step in the dance of the Laysan albatross (*Diomedea immutabilis*). Laysan Island, Hawaiian Bird Reservation. Photograph by Alexander Wetmore. Courtesy of the Bureau of Biological Survey

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with such facility, in fact, that they can walk up the side of a boarded inclosure to a height of several feet, and it has proved difficult at times to keep them in captivity.

The young of certain hawks, such as the red-tailed and the marsh hawks (Plate 45), are covered with white down when they hatch but are helpless and confined to the nest for a period of many days afterward. During this time the parent birds remain in constant attendance, brooding the young to protect them from sun and cold and supplying them with food. The young develop slowly, and in the process the permanent plumage gradually replaces the body down and the feathers of wing and tail grow. When nearly grown the fledglings spend much time exercising, standing erect in the nest and waving their wings; and as they become larger and stronger they often raise themselves completely from the nest platform for a few seconds. Eventually they essay a flight into the air away from the nest, and soon they become as expert on the wing as their parents and take up their own search for food.

Young albatrosses go through a somewhat similar development, though the mother lays but a single egg and deposits that on the ground. The Laysan albatross (Plate 47), which nests in the small islands of the Hawaiian Bird Reservation, in October or November lays its egg in a slight depression on the open stretches of coral sand or on any level space it can find on some rocky hill. The young bird when first hatched is small and helpless but grows with amazing rapidity. In a short time it sits up and waddles about, leaving the original nesting cavity. It often wanders for many yards, making slight excavations in the sand at need, and these it occupies as temporary nests. An abundance of soft, gray down covers its body at this stage, so that it appears as woolly as a lamb. It sits with the body erect but resting on the abdomen, as its legs are not strong enough to bear its heavy body. Its parents are very attentive, caring for it assiduously, feeding it with an abundance of squid which they capture at sea.

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Feeding is entirely by regurgitation. The parent bird, returning with food, rests for a time beside the infant, while the latter begs for its meal by nibbling at the adult's bill. Finally the parent rises to a crouching position, with the breast nearly touching the ground, and opens the mouth, whereupon the youngster thrusts its open beak crosswise between the mandibles of the adult. The food comes up into the parent's throat in the form of a bolus, which is received and swallowed eagerly by the young bird.

Young albatrosses grow rapidly and by April begin to replace their down with the feathering of the adult. By this time they have become as large in body as their parents, and they begin to stand and walk about. This is the stage at which the parents, hitherto most attentive and solicitous, forsake their breeding grounds for the open sea, leaving the young entirely to their own devices. For three or four weeks the young albatrosses wander about, maintaining their bodily activity from the fat stored up in their previous season of plenty, so that, though they obtain no food, they are able to complete their growth of feathers. Their wings grow to normal size, and the adolescent birds, feeling the coming of their volant powers, stand for minutes at a time with their broad pinions spread in the steady sweep of the trade winds which during the day blow unceasingly across their island haunts. The birds face the wind and as their wings strengthen they begin to raise their feet and to glide forward on widespread wings against the breeze. As their power to maintain equilibrium increases the birds take longer gliding flights until finally they are carried out over the water. After soaring a few yards, they usually tumble down and drift with the wind until they are blown against the shore, when they walk out on the sands to essay further attempts at flight. Eventually they are able to take the air and soar away to sea. The provision that causes young albatrosses to sail against the wind proves a vital safeguard; for if, in their early attempts, they were to fly with the wind when it is blowing out to



Group of brown pelicans (*Pelecanus o. occidentalis*) with nests and young. Pelican Island Reservation, Sebastian, Florida. Photograph by Alexander Wetmore. Courtesy of the Bureau of Biological Survey



Brown thrasher (*Toxostoma rufum*) with nest and unfledged young. Photograph by Dr. Frank N. Wilson

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sea, they would fall into the water, to be blown steadily away from land and so be destroyed eventually by sharks or by drowning.

Young brown pelicans come into the world helpless and entirely naked, and truly they are repulsive looking with their livid skin and swollen heads, which they can barely hold erect long enough to take food into their mouths. Not until they are ten or more days old does down begin to appear on their bodies and the growth of the final or fall plumage begins when they are completely covered with down. The parents feed the young entirely by regurgitation, the food consisting of fish, which is partly digested in the stomach of the adult before being given to the young. As the young increase in size, they are given small whole fish which the old birds carry to their nests in their stomachs. The great pouch under the bill, incidentally and contrary to popular belief, is used only as a seine or net to capture food and not as a carrying basket. When small the young are carefully fed with drops of liquid food from the tip of the parent's bill; but as they become large and active, the adult opens its bill and the young plunge head and neck into the vast throat, digging and prodding for the food that is regurgitated for them, sometimes seemingly in danger of being themselves engulfed. When the weather is cool at Pelican Island (Plate 48), a reservation on the east coast of Florida where the brown pelican is guarded that it may breed in safety, fish may be difficult to secure. Then the young squabble considerably, the larger birds worrying those that have been fed to make them regurgitate their meal, which the bullies gobble up. Sometimes nearly grown birds become so ravenous that when their smaller companions are slow in responding to their demands, they seize and swallow them entire, fish and all—an act of unmitigated cannibalism.

Pelicans sometimes go remarkable distances to secure food for their young. A considerable colony of white

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pelicans nests on an island in the northern part of Great Salt Lake. As the briny waters of the lake contain no fish, the pelicans must fly across to the fresh-water rivers which flow into the lake thirty-five to sixty miles away to secure food. On their return, in addition to having often to fly against adverse winds that make progress exceedingly slow and laborious, they carry a burden of fish for their youngsters.

Young humming birds when hatched have short bills like the swifts, to which they are closely related. They, also, are fed by regurgitation, a process that appears most dangerous in their case, as the parent stabs her needlelike bill down the throats of her offspring for all the world as though she were going to impale them.

The adult toucan of the tropical forests is distinguished by its enormous beak, but as in the young humming bird the bill of the newly hatched toucan is not particularly notable for its size. Its greatest development takes place when the bird is assuming adult stature. Young toucans exhibit a peculiar structure in the shape of a heel pad on the upper end of the tarsus or bare portion of the lower leg. This consists of a thickened plate, the surface of which is studded with projecting points of horny material. The entire structure sloughs off when the bird is grown. As the young are weak and unable to stand erect for some time, these heel pads provide supports on which the bird rests, the roughened surface assisting them to move about and at the same time protecting the leg from abrasion by the rough surface of the tree hollows in which they are born. Similar heel pads are found in young woodpeckers, which also are hatched and reared in tree holes and for a period are too weak to stand entirely erect.

The young of perching birds are all hatched in a helpless condition and remain for ten days or more in the nest before they grow to a stage where they can venture out (Plate 49). Most of them, when first hatched, have a scanty growth of hairlike down on the crown and back,

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so scanty, in fact, as not to have any particular importance in keeping them warm. A few species of this group, for example the bluejay and loggerhead shrike, are hatched entirely naked. When very small, most perching nestlings are fed by regurgitation from the stomach or crop of the parent, but as soon as they have grown a little, they are fed on food brought to the nest in the parent's bill.

Sanitation is an important matter, if disease is to be avoided, for young birds that must remain in the nest for some time. Young herons and hawks seem instinctively to void their excrement forcibly to a distance over the edge of the nest. Young vireos, warblers, thrushes, and related forms void in the excrement an albuminous substance which envelops it and causes close coherence, so that the mass may be seized in the bill of the parent and removed to a distance. Young house finches and siskins void over the edge of the nest as soon as they are large enough to move about. Only a few birds, such as the hoopoes and woodpeckers, pay no apparent attention to this matter of cleanliness, with the result that their nests become extremely foul and ill-smelling toward the close of their period of occupancy.

In young perching birds of all kinds, in woodpeckers, and in many other groups, the corners of the mouth or gape are soft and swollen and often light-colored. When it wants food the young bird stretches its neck up full length, keeping its mouth open wide so that the light corners are very prominent and assist in directing attention to the mouth cavity. These light margins seem particularly useful to birds that nest in holes, inasmuch as they indicate the exact position of the mouth to the parent, whose eyesight may be somewhat dulled by the sudden transition from the brightness of day to the obscurity of the nest cavity. Young weaver finches that are hatched in covered nests have a considerable variety of mouth markings in addition to those at the corners of the gape. The Gouldian finches have blue, wartlike pro-

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jections on the roof of the mouth that are said to be semiluminous. These peculiar developments may also serve some protective purpose against timid enemies, for they are somewhat startling when suddenly displayed and are often accompanied by hissing and other peculiar noises which might deter an intruder in the nest.

CHAPTER IX

VOICE AND OTHER SOUNDS

THE songs of many birds are pleasing and melodious to human ears, and with beautiful color and sprightly actions constitute much of the charm of the feathered host. As these lines are written there come through an open window from the park outside the cadenced notes of a mocking bird and the clear songs of robins, announcing to the world that spring has come and extending an invitation to all to enjoy with the small musicians the outdoor delights of clear air and unfolding vegetation.

The human voice is produced in the larynx, in the upper part of the throat; but bird notes emanate from another voice box, called the syrinx, located at the lower end of the windpipe, where this divides to send a bronchial tube to each of the lungs. The syrinx has firm walls of strong cartilage formed at the lower end of the windpipe and the upper ends of the bronchial tubes, its appearance varying considerably in different groups of birds. The chamber of the syrinx contains delicate membranes, so controlled by slender muscles that their tension may be changed. Air expelled from the lungs produces sound in passing over these membranes, and the pitch varies as the tension changes. Birds also possess a larynx, like that found in mammals, at the upper end of the trachea; but so far as known this has no function in voice production except to modulate somewhat sounds produced in the lower organ. The external musculature of the syrinx varies considerably in different species, being strong and well developed in the oscine or higher groups of singing birds and almost absent in some of the vultures.

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Bird sounds vary extensively in power and kind and in the manner in which they affect the human ear. The adult brown pelican and the turkey vulture, so far as known, are voiceless except for a hissing sound produced by the aspiration of air expelled forcibly from the wind-pipe. This is especially curious since the young of both these species continually produce rough, uncouth noises in begging for food, and the young vulture makes the same sounds in attempting to frighten away enemies. Vultures frequently nest in small caverns about rocks. When the partly grown young are disturbed, they turn their backs to the observer, spread their wings, and bow their heads, so that they have no resemblance to an ordinary bird. At the same time they utter a curious growling call, suggestive of some angry cat, and suddenly strike the tips of the wings on the ground to produce a startling rattle.

In contrast to such crude vocalizations, the brown thrasher pours forth a stream of couplets, repeated or varied at will. The clear, whistled calls of the thrushes afford to the understanding human ear the pleasure that otherwise only a great musician can give. Between the two extremes represented by the vultures and the thrushes, there intervenes an almost endless variety of bird sounds either pleasing or decidedly displeasing to man. Some people complain of the doleful cooing of the mourning dove and of the more emphatic utterance of the white-winged dove of the Southwest. The chattering of the English, or house, sparrow, as he endeavors to call his mate to his side to examine his selection of a wonderful site for a home, is unpleasant to some human ears, as may be the raucous calls of the great blue heron. It must be remembered, however, that these sounds are meant for certain ears alone, to which they come as the sweetest of tones, and so accomplish their purpose, no matter how much unimportant outsiders may disapprove.

The mating call of the male rhea of South America is a deep, booming sound, deceptive to the ear because it fre-

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quently seems as loud at a distance as when near at hand, so that it is difficult to tell the location of the performer. The male ostrich gives utterance to a hoarse, mournful cry which has been likened to the roaring of a lion. Cassowaries have very peculiar grunting or bellowing notes.

Among the strange sounds produced by birds that comparatively few persons ever hear is the call of the wedge-tailed shearwater, a relative of the albatross, which nests in tremendous colonies on small islands in the Pacific. Shearwaters are most active during the night, moving about, working on their nesting burrows, and fighting viciously with one another in prolonged battles that may continue until one or both combatants are exhausted. The love song of this bird consists of a series of shrieks and groans, indescribable in human speech, and which, repeated steadily outside a tent door, can exasperate the tired naturalist to the ultimate degree. The ear may single out the notes of one or two individuals near at hand, but at a distance the calls of thousands of these birds combine to produce a vast volume of sound, in which the blending of many notes removes the harshness of single calls. From a distance the sound resembles somewhat the mingled calling of bands of sheep, so that in hearing them one might imagine himself on some sheep range rather than on a remote island.

Great colonies of white-winged doves sometimes nest together in groves of thorny mesquite trees in Arizona and New Mexico. And multitudes of individuals send forth their calls continuously, producing a vast volume of sound. Males of this species have two distinct songs, which they sing without apparent choice. One of these efforts may be represented by the syllables *who hoo whoo hoo-oo*, the first three notes being gruff and abrupt, and the last, which is strongly accented, somewhat prolonged. The other song, longer and more complicated, which may be represented by the notes *who hoo, whoo hoo, hoo-ah'*; *hoo-hoo-ah'*; *who-oo*, is more musical to the ear. At times

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the doves repeat one or the other of these songs for long intervals, while at others the two forms are given in rapid alternation. Seated in their populous rookeries, the listener may clearly distinguish the songs of one or two individuals near at hand, but all other notes seem to come from a distance and are blended so that individual utterances are picked out with difficulty. The volume of sound produced by large colonies of these doves can be heard distinctly a mile away, and yet the tones so completely lack harshness that they are not deafening near at hand. On the contrary, the whole blends into an undertone, continuous as the soft rippling of water, and, like that sound, of so vague a nature that the ears soon grow accustomed and cease almost to note it. Although it seems in its continuity to fill the air completely, other bird sounds—like the cooing of a mourning dove or the song of a red-winged blackbird—or such a noise as the stamping of a horse are heard clearly even at some distance.

The songs of most birds, though they may be repeated constantly for a considerable period, are uttered singly—not in chorus like those just described. The early morning spring song of the robin is ordinarily clearer and more regular than its song of later in the day, which is often broken and interrupted by harsher notes. The cardinal gives a clear, ringing whistle, as does the rose-breasted grosbeak. The song sparrow, distributed through a vast area in North America and varying greatly in color and form, has a song that is quite uniform in sound throughout the bird's range. The species of Unalaska Island, a veritable giant of its kind—as large as a chewink—sings as pleasantly and in much the same tone as the common species of the eastern United States, a song without great pretense, but cheerful and pleasing.

The songs of certain birds seem to human ears scarcely to merit the name. Of such is that of the Henslow's sparrow, an elusive little inhabitant of grassy meadows in the Central and Eastern States, which from some weed stalk

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in spring utters a low, lisping double note, barely audible at a distance of a hundred yards. Sharp ears may detect the song but as it is ventriloquial in tone some time may elapse before its author is located. A relative, the grasshopper sparrow, derives its common name from its insignificant song, which is like the low stridulation of an insect. The Cape May warbler of the Eastern States opens his mouth wide to utter a few lisping notes that often may not be heard by the human ear, though the bird's throat is seen to move and the singer is only a few yards away. Contrast these meager sounds with the full-voiced shouting of a crane or the vociferous crowing of a rooster and the range of tone in avian utterance is readily appreciated.

Some species of birds are not satisfied with their own vocabulary but, extremely imitative, borrow generously from others. The most famous mimic among American species is the mocking bird, whose songs, sung all through the breeding season from tree top, house roof, or chimney, are replete with imitations of other birds. These songs are reproduced usually in such perfection that their falsity would not be suspected were it not that they pour forth in rapid medley mingled with calls proper to the repertoire of the gifted songster himself. The starling of western Europe, now naturalized in the eastern United States, is also a gifted mimic, and mingles with its own rattling, clattering, and whistling utterances imitations of the songs of the bluebird, wood pewee, quail, meadow lark, and other species peculiar to the land of its adoption.

Some of the parrots, particularly the African gray parrot and, in the New World, certain Amazon parrots, readily learn to imitate sounds, especially of human speech and laughter, and frequently use their borrowed phrases with such opportune effect as to simulate an understanding of the meaning of the sounds they utter. Individuals among them vary in their imitative powers from extreme aptness to stupidity. They tend to pick up

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phrases uttered constantly in their hearing, particularly words given with emphasis or vehemence. The vocabulary of gifted individuals may be considerable, though ordinarily the "speech" of parrots is restricted to a relatively few stock phrases. By Amazon parrots, at least, this imitative habit seems to be exercised solely when in captivity, as, during a considerable experience with several species of this group in a wild state, I have never heard any of them show the slightest tendency to imitate the calls of other birds or other sounds about them. They confine their cries to the shrieking, squalling, and chattering that constitute their normal notes. The imitative habit is developed early in life, as captive birds in most instances are individuals secured while young.

Various other species of birds share with the parrots the ability to imitate sounds. The wattled myna of India and the Malay Peninsula, slightly larger than an ordinary jay, with glossy, violet-black plumage and curious fleshy lappets or wattles on the sides of the head, learns readily to repeat phrases of human speech. One especially gifted myna, the survivor of a pair in the National Zoological Park, has learned to say a variety of phrases, some of which it has been taught and some of which it has picked up casually. For a time after the loss of its companion it was not unusual for this bird to remark to a visitor, "The other one died!" This startling statement it had picked up from hearing the keeper make this explanation to persons inquiring after the missing bird. Curiously enough, other mynas seem to learn more readily from this individual than from attempts to train them independently. Two others have been placed at different times in the adjacent cage, and in a few weeks each has assimilated the phrases and sounds that make up the repertoire of the original myna.

Crows, ravens, and magpies have some ability in mimicry of human speech, though this is confined usually to a few short words or simple phrases. It is a current misap-

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prehension that the tongue of these birds must be split to enable them to articulate human speech, but no known basis exists for such a belief; when the practice is followed, it only imposes a needless cruelty. In all probability the birds will develop greater imitative powers if not thus injured. The origin for this curious belief may lie in the fact that the tongue of members of the crow and jay family is naturally divided at the tip for a short distance.

Imitation of human speech by birds is mimicry and nothing else. Frequently the copied sounds become definitely associated with persons, actions, or certain needs of the bird itself and are given in reaction to such stimuli, when it may appear that the bird is conscious of the meaning of its utterances to mankind. These instances must be explained, however, by the fact that the bird has learned the phrases in association with definite stimuli, such as the sight of food, and are, therefore, not evidence of an understanding of abstract expression.

Bird song centers mainly around the sex impulse and, therefore, attains fullest and finest expression prior to and during the breeding season. It is both a proclamation of virile vigor on the part of the male and a notice to his world that he is prepared to take a mate. The song period of some birds, such as the bobwhite (Plate 50), is remarkably short. This species is now believed to cease its musical calls of *ah bob white* as soon as a partner for the breeding season has been found. The mocking bird, on the other hand, sings constantly during spring and early summer, and during the height of the nesting season even continues its serenades throughout moonlit nights. Most species cease singing with the close of the breeding period, when the molting season arrives and the bird becomes inactive and sluggish and seemingly of lower general vitality than at any other time of the year. In some birds the organs of voice actually appear to be affected while they are molting. The song sparrow, for example, utters a broken, warbling song at this season so unlike its cheery

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melody of a few weeks earlier as scarcely to be recognized until the musician is seen. When the new coat of feathers is completely grown, a few species, like the meadow lark, enter on a second period of song that continues during the pleasant weeks of early fall. Most birds, however, remain comparatively mute until the approach of spring again arouses them to vocal effort. Only a few, like the Carolina wren, sing constantly every month in the year, even the molting season being unable to silence them completely.

As one of the displays of the mating season, some species of birds rise to sing in the air. The mocking bird does this regularly, flying to display prominently the white markings in wing and tail, which are as flamboyant and striking as the musical notes that accompany them. The lark bunting of our western prairies rises a few yards above the earth, to drift slowly down with extended, tremulous wings while it gives out its pleasant song. The horned lark, though it sings regularly from some tiny hillock or stone, may soar high in the air like its relative, the Old World skylark, and fly about for many minutes in full song. A few birds, as the ovenbird, reserve a special song for use only on the wing, and this is heard only on rare occasions. The indigo bunting may sing occasionally on the wing during the nesting season and does so regularly in early fall when the birds congregate among weeds in low, wet places, awaiting the time for the southward migration. At such times the males rise twenty or thirty yards in the air at intervals during the morning and evening to utter their characteristic songs, and then drop back to cover.

Birds have, in addition to song, many other calls—expressive of the social instinct, warning of the approach of possible danger, announcing the presence of food, or calls of petulance or anger. Vocabulary varies much in different species and may be extended or very limited. Mention has been made of the snakelike hissing with which pelicans and turkey vultures express displeasure at being disturbed. To give voice to the same sentiment,



Female bobwhite (*Colinus c. virginianus*), an upland game bird. The throat of the male is white, while that of the female is brown. Photograph by Dr. Frank N. Wilson



Male ruffed grouse (*Bonasa umbellus*) in the act of drumming. The bird mounts a log, rock, or stump, stands erect, and with short, quick strokes of the wings produces a resonant love song. Photograph by Dr. Arthur A. Allen

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bluejays squall harshly, their notes serving to alarm not only their own kind but also other birds and animals that need to be alert to escape their enemies. The cries of a killdeer, protesting human passage near its nest, may alarm other shore birds and ducks; and as the sharp eyes of the killdeer detect anything unusual the instant it appears, its cries frequently serve to keep near-by birds disturbed when ornithologists might wish that the latter would remain quiet for observation. Birds with young active enough to run about as soon as hatched have soft calls that serve to hold the family together. Notes of anger or fear often resemble one another closely and may be ordinary calls uttered with extra vehemence or emphasis. Live birds being handled for banding have been known occasionally to sing while in the hands of their captors. A young night heron, standing with neck drawn in, suddenly darts out its head at an intruder and with wide-open mouth utters a vociferous squawk that startles any except the steadiest of nerves. Chickadees, which nest in holes, when disturbed on the nest sometimes give voice to a low hiss, which may unpleasantly suggest a snake concealed in the darkness of the cavity.

Birds that live in loose bands frequently have a variety of conversational notes, which often seem simply an expression of garrulousness but probably serve to indicate to the little flock the whereabouts of its members and so give friendly assurance of near-by company. Birds like the bobwhite (Plate 50) that run about in closely associated groups under cover of heavy growths of weeds, grass, and brush, utter a mellow sound when separated from one another which serves to reassemble the scattered flock. The low calls of titmice and other small birds that travel in little bands except when nesting must serve to keep the individuals in contact as they move about.

The woodpeckers have a variety of calls of which some are strange and some are pleasing and musical, but during the breeding season these birds also substitute, in part, for

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vocal music a variety of drumming sounds made by hammering with their bills on wood. Each species plays its own composition from which there is little variation, so that a little attention enables one to distinguish the sounds produced by each of a number of our common species in spite of the fact that several species produce a closely similar rat-a-tat. The males are the regular drummers, though they are occasionally answered by the females, whose drumming is, however, weaker and less effective.

The male flicker, in April, seeks a dry, dead limb in the territory he has chosen for his summer home, and with a series of almost incredibly rapid blows of his bill produces a loud, resounding tattoo whose beats come several to the second. Changing position slightly, he rattles again, this time sending out a rolling beat in a different tone, a variation in his music which he seems to enjoy. During intervals of rest from his drumming he shouts his ordinary calls in a loud voice. He is versatile as a drummer and has a quick eye for a proper sounding board for his performances. When he chances to select a metal gutter or roof above a bedroom window for an early sunrise performance his efforts may not be wholeheartedly appreciated by those persons endeavoring to sleep within.

The male ruffed grouse, a bird as large as a very small bantam, which is known in the North as a "partridge" and in the South as a "pheasant," produces a loud drumming sound in another manner. Each bird has certain stumps, fallen logs, mounds, or stones to which he resorts to "drum." Standing very erect, he raises his wings quickly until they almost meet behind his back and then brings them suddenly forward until they almost touch his breast (Plate 51). He repeats this motion slowly several times but with slightly increasing rapidity, then suddenly changes to a quicker vibration of great force, and all at once abruptly ceases. The first notes are deep and resonant, coming to the ear like the beat of some tremendous heart—a sound that so fills the air with its



Rufous humming bird (*Selasphorus rufus*), above, and Anna's humming bird (*Calypte anna*), below, of the western United States. Both these individuals are males. A female rufous hummer is shown at the right, probing flowers

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vibrant quality as to be felt rather than heard. The final rattle blurs together with a rumble like the muttering of distant thunder.

The male turkey, strutting before his harem, spreads his tail, fluffs his feathers, and drops his wings stiffly to the ground, rubbing their tips over the surface with a rattling, scratching sound, and at the same time producing a curious rumble in his body that may possibly come from some tension of the air sacs. The peacock, in strutting, frequently shakes the great upper tail coverts that form his resplendent train, producing a dry rattle as the shafts of the feathers strike one another lightly. The male ruddy duck in display fills a specially developed air sac in his throat and then, as he swims about, rattles his bill up and down so that its tip strikes the feathers over this resonating chamber, producing a queer, clicking sound that is followed by a low, vocal note.

Storks produce a great rattling noise by striking their opened mandibles quickly together; while owls, when excited, open the jaws for a moment and then close them suddenly with a loud snap that threatens the supposed enemy. The great shoebill stork of Africa solemnly shakes his head and opens and closes his mouth with a loud *clap clap* of his bill. The kiwi of New Zealand, when disturbed, evinces his irritation by stamping with one foot upon the ground.

CHAPTER X

STUDIES AFIELD AND IN THE LABORATORY

ORNITHOLOGY appeals equally to the ardent nature lover, for whom a humming bird hovering before a flower is a wonderful mixture of brilliant color and sprightly movement, and to the highly trained specialist, who derives the same aesthetic pleasure from such a sight while recalling, perhaps, that the humming bird is a ten-primaried, anisodactylous, holorhinal form related rather closely to the Micropodidae or swifts! The study of birds, then, may be vocation or avocation, career or mental diversion.

The seasonal bird-study groups, who saunter forth with their field glasses when the spring calls them out, find their pleasure in identifying migrants, of which they may list as many as a hundred different species in a single area. Those who have discovered the greater importance and possibly greater pleasure, also, of studying the habits of individual birds, can follow their bent the whole year round. Such students learn, when observing the shier birds, to speak cautiously or to remain silent, to avoid abrupt, disturbing movements, and to utilize the cover of grass, rushes, or bushes as partial concealment. They learn, when working among colonizing birds, where close observation is often possible, to shade their eyes or to avoid looking intently and directly at the bird they desire to approach, as wary individuals notice immediately that they are under scrutiny. Incidentally, it is often possible to approach shy birds in the open by walking slowly and cautiously sideways, while avoiding direct glances at the object of approach. By these methods I have frequently

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come within ten or twelve feet of adult birds in breeding colonies of pelicans and other species without arousing them to alarm. Finally, the more serious amateur learns also to develop his ear as well as his eye, for the calls and songs of birds bring individuals to attention that would otherwise be missed.

Bird banding as an adjunct to ornithological studies, as has been pointed out, results in valuable information and pleasure to the worker. Photography is another such adjunct, made use of often during the nesting season, since nests, eggs, and young birds furnish interesting subjects and in addition are certain to draw adult birds within range of the camera lens. The photographer may utilize feeding stands (Plate 53) and bird baths, which will attract birds throughout the year; and, of course, some kinds of birds may be photographed without these aids in their natural haunts. In recent years motion-picture photography has much enlarged the scope of this field and has yielded many intensely interesting and important life studies.

The professional ornithologist, while he may delight in the types of study that have been described, goes further in his researches to investigate minutely form, color, and the detail of structure in the various kinds of birds. For this type of investigation he preserves specimens of birds as study skins or as mounts in natural attitudes, specimens as skeletons, and, for dissection, fragments or entire birds in alcohol or other fluid. The larger museums have accumulated great collections for such research; and it is study of these museum collections that has yielded knowledge of the characters by which birds are classified and distinguished, the foundation upon which the science of ornithology rests.

The growth of great museum collections has already been touched upon somewhat. Systematic collecting in the field makes an essential contribution thereto, and the organization of expeditions solely for ornithological ex-

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ploration is not at all rare. In the usual routine of field work the collector sallies forth in early morning, armed with gun, notebook, and field glasses—generally, also, with a small camera in his hunting-coat pocket—and remains afield until noon. The afternoon he spends in preparing his specimens for preservation and in writing his notes, tasks that may last well into the evening. For ordinary collecting I use a double-barreled, sixteen-gauge shotgun, carrying a fully loaded shell in one barrel and in the other a small steel tube or reducing chamber, called an auxiliary barrel (“aux” for short), that fits into the shotgun barrel like a shell and is chambered to take a .32-caliber cartridge. I carry an assortment of ordinary shells loaded with Nos. 2, 6, 8, 10, and 12 shot (the last of which is very fine and small) and a quantity of the .32 shells loaded with No. 12 shot. The heavy loads serve for birds at a distance, while the .32 cartridges are used for small birds near at hand. The experienced collector does not shoot birds indiscriminately but selects only the most desirable, attempting always, in country that is not well known, to obtain at least one example of each kind of bird occurring in the locality.

I recall vividly my first day afield in a tropical region, which came during investigations that took me to the island of Porto Rico for the period of a year. Reading and the examination of specimens in Washington had fully familiarized me with the peculiar birds to be found on this island. Transporting my field outfit late on a Sunday afternoon to the village of Río Piedras, shortly after day-break the following morning found me walking along a country road. Almost immediately I sighted a small bird hopping about in the top of a densely leaved mango tree. Pushing hastily through a maya hedge—whose thorns were remembered later—in a moment I had the bird in hand, eager to examine my first specimen of the strange forms peculiar to the island. But, in spite of the thorough knowledge obtained beforehand, I did not recognize the



Feeding shelves on which food is placed to attract birds about houses. Purple finches are enjoying a meal.
Photograph by C. L. Whittle



Kookaburra, or great brown kingfisher (*Dacelo novaeguinae*) of Australia. Photograph by Charles Barrett

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species at once; and I turned it over several times in perplexed examination before suddenly, when my excitement had abated, I realized that it was a parula warbler, a migrant from North America, with which I had been familiar since childhood! The peculiar birds came later, however, and included one beautiful form of hawk new to science.

As soon as a dead bird has been retrieved by the collector, it is examined carefully and all drops of blood removed from the plumage, a little dry earth or cotton is put on the shot holes, the throat is plugged with cotton, and the specimen, with feathers carefully smoothed, is dropped head first into a paper cornucopia, where it carries safely and without injury to the delicate plumage. Meanwhile, a brief notation on the bird's song or notes has been scribbled in the pocket notebook; and possibly a rare bird fly, that lives only among feathers, has been captured and dropped in a little vial of alcohol for preservation. The morning passes quickly in searching out strange sounds and calls, in investigating thickets and savannas, and in observing the many interesting mannerisms of the feathered inhabitants encountered. On return to camp or lodgings, the morning's take of specimens is unwrapped and arranged, notes are made on the color of eyes, bills, and feet, the specimens are recorded in a numbered catalogue, and a label is prepared for each, on which is carefully written the exact locality, the date, the name of the collector, and the catalogue number. The sex is entered when the body has been skinned. There follows then the labor of preservation, that the specimens may be sent in proper condition to the museum.

With scalpel, scissors, tweezers, needle and thread, fine corn meal, and powdered arsenic at hand, the first bird is laid on the skinning table and a cut made for the full length of the abdomen, through which the bird is skinned, the skin being turned inside out during the process. By a liberal application of corn meal all blood is absorbed and

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the feathers kept clean. The bones of legs, wings, and skull remain with the skin, but all flesh and fat are removed. The skin is then dusted with powdered arsenic as a preservative against insects (the hind foot of a rabbit with the claws cut off makes an excellent arsenic brush), turned right side out once more, and the feathers smoothed in place by a sharp shake. It remains to stuff the specimen—with cotton, if small, or with tow or excelsior, if large—and to sew up the cut in the abdomen. Finally, the legs are crossed and tied together, the label is attached to one leg, the feathers are carefully arranged, and the specimen is wrapped in a thin sheet of long-fibered cotton and laid away in a tray to dry. In this condition it reaches the museum, where it is known as a study skin (see Plate 3). In appearance it is simply a dead bird laid on its back with bill and feet extended and wings carefully in place at the sides. In the museum certain interesting specimens are softened and then mounted in lifelike attitudes by taxidermists for public display, but the majority are kept as study skins for scientific investigation.

The beginner finds the preparation of specimens extremely slow and tedious. The skin of most birds is tender, the feathers seem to fall out at a touch, and there are many other difficulties. Practice, however, soon makes the process automatic and swift; and the expert prepares from fifteen to thirty small birds in a day with ease, and often the number may reach fifty.

When several study skins of some bird of peculiar type have been prepared, the experienced ornithologist cuts an opening into the abdominal cavity of one or two additional birds of the same type and drops them entire into alcohol to preserve them for subsequent dissection. He also prepares one or two skeletons of each kind of bird secured by removing the skin with the feathers, cutting away the muscles of breast, legs, and wings, and removing the viscera, being careful to note the sex of the specimen. If the species is certainly known, the name is entered in the

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catalogue and on the label; if not, the feathers are left on the head, wings, and tail to permit subsequent identification. The skeleton is only roughly cleaned, care being taken to avoid cutting any of the bony processes, and then folded into a compact bundle, with wings and legs against the body and head turned on the back, in which position it is held by wrapping it firmly but not too tightly with a strong thread or light twine. A string is tied to the neck vertebrae and the specimen hung up to dry where it will be safe from dogs, cats, and other destructive creatures. On reaching the museum these specimens are properly cleaned by skilled osteologists and made available for study.

The experiences of the professional ornithologist in the field may be illustrated briefly by the following account of an expedition I once undertook during a year in South America:

In the first week in August, which is near the close of the winter season in the Southern Hemisphere, I reached the little town of Formosa, on the Paraguay River in the northern part of Argentina, and entrained for Fontana, otherwise called Kilometro 182, this being its distance inland from the river. The railroad was a government enterprise, built to open new country for settlement, and only two trains operated each week. On the morning of my departure porters busily weighed up baggage and, with evil-looking paste, stuck a slip of pink paper bearing the destination on each piece. This seemed a careless procedure but proved quite effective; for during a year, in thousands of miles of such travel, I lost nothing from my equipment. Seemingly everything may be checked; even two live goats tethered to a post had each a pink slip pasted about one horn.

Suddenly a bell on the station platform rang, a train guard blew a whistle, and with a jerk our train started. After traveling a comparatively short distance it began to traverse wild and unsettled land. The term Chaco (Plate 55) is applied to a tremendous area of broad, nearly

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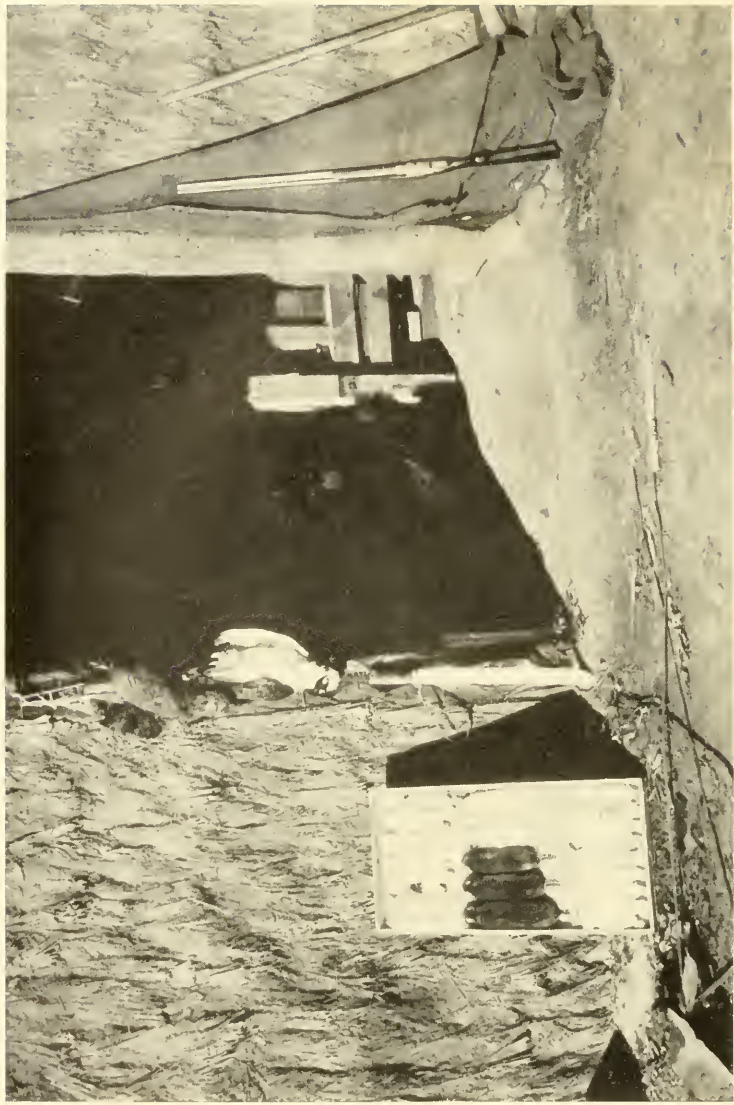
level country, covered by alternate forest and marshy savanna, that lies just west of the Paraguay River, extending northward from the northern part of the province of Santa Fé through the territories of Chaco and Formosa and western Paraguay into Bolivia. For miles our train followed a roadbed built through a seemingly endless *estero*, or slough, with broad swamps and prairies on either hand dotted with slender-trunked palms interspersed with matted growths of saw-edged grass and rushes and bordered by groves of low-growing hardwood trees, prominent among which was the quebracho, valuable for its dye product. Hundreds and hundreds of acres of marshy ground were covered with the hills of termites, or white ants, built up three or four feet above the surrounding level to raise them above the inundations of the summer rains. At intervals the train crept out to higher ground and stopped for a few moments at some little station with a cluster of low houses or grass-thatched huts about it, where parcels of freight and a passenger or two were unloaded and men and women with much gesticulation bargained for fresh meat at the *carniceria* or butcher shop installed in one of the cars of the train.

Away from these stations there was no sign of human habitation. Bands of rheas, flocks of maguari storks, courlans, and other large birds abounded, giving promise of good collecting grounds. In mid-afternoon I arrived at Fontana, and then, at the hospitable invitation of Don Pedro, a train acquaintance, continued by oxcart for fifteen kilometers farther to the Estancia Linda Vista. My energetic young host had emigrated to Argentina from Poland and, four years before our meeting, had come to the Chaco to establish a ranch. On learning that my purpose was to make collections and observations of birds and other animals, he informed me that when a student in Warsaw natural history had been his principal interest.

At Linda Vista, aside from two hundred acres under cultivation, the Chaco remained in its primitive condi-



A wayside *boliche*, or country store, in the Argentine Chaco. Photograph by Alexander Wetmore.
Courtesy of the Bureau of Biological Survey



Work quarters at the Estancia Linda Vista, Formosa, Argentina. Photograph by Alexander Wetmore. Courtesy of the Bureau of Biological Survey

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tion. Open savannas and small groves covered great areas, while extensive forests grew along small, sluggish streams known as *riachos*. These forests contained a dense, jungle undergrowth, through which trails had to be cut with a machete. The enervating rains of summer were far off; and, though the days were frequently hot, frost came regularly at night, so that the mornings and evenings were cool and bracing.

Birds abounded in number and variety. Collecting, preparing specimens (Plate 56), and writing notes by the aid of candle or electric torch in the evening ate up the days from five in the morning till nine at night. Several lagoons, partly covered with mats of floating vegetation that drifted from side to side with the wind, harbored many water birds. They were, however, often difficult to secure. I frequently shot tiger bitterns or other swamp-loving species only to have them fall in the deep water out of reach. The lagoons were the home of the palometa, a fish living in schools that is apt viciously to attack wounded animals on the surface and, when excited by the presence of blood, to tear to pieces any land creature that enters the water. In some localities the palometa attacks on slight provocation, while in others it offers no trouble. It was always wise, therefore, to watch quietly for ten or fifteen minutes to see if the dead birds floating in the water were to be molested. If all remained quiet, one could swim out slowly and cautiously through the black water to retrieve the specimen, avoiding the slightest noise or commotion that might draw undue attention.

I inquired for a canoe at an Indian encampment by one lagoon; and, for a few cents, a friendly native fashioned a balsa, or raft. He cut great armfuls of eight-foot cattails, tied them into four bundles, and with a rush rope bound them together into a crude craft three or four feet wide. Kneeling on this somewhat unstable craft I paddled out to collect gallinules and grebes and to secure a beautiful little flycatcher (*Arundinicola leucocephala*) with a

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pure-white head, which lived in rushes growing in deep water and could not be obtained from shore. At another lagoon, where suitable cat-tails for a balsa were not available, Don Pedro cut down a great *palo borracho*, a tree with a much swollen trunk, and from this took a section eighteen feet long. (The bark of the *palo borracho* is three-fourths of an inch thick and as hard as flint, while the inside is soft and moist like the inside of a cornstalk.) This section was soon hewed out into a huge *cachiveo*, a crude sort of canoe, which when launched served admirably for collecting birds. Though this craft was too unwieldy to paddle easily, I was able, by waiting for days of favorable wind, to drift down the open lagoon. A screen or blind of rushes built in the bow enabled me to get within gunshot of great hawks feeding in the marsh and many other shy birds.

The size of the *cachiveo* prevented pushing it through the rushes, so that it was necessary to swim for many birds, always circumspectly because of the biting palometa. Birds and other specimens were obtained in such abundance that the afternoons were hardly long enough to prepare them. The skinning table was set up in a small shed, and a swinging shelf of rough boards was hung from the rafters so that the specimens could be dried without being devoured by wild rats or other creatures.

In the evenings, after sundown, the work bulls of the *estancia*, turned out to graze in the savannas, frequently came running madly to the corral, disturbed by the passing of a jaguar or puma. Small bands of Toba Indians came regularly to camp near by and to trade in Don Pedro's little store. They stood at the gate of the corral until some one saw them and spoke to Lobo, the huge watchdog, who otherwise would fly at them without a sound. Once admitted, they came up to a little window to exchange skins of animals for needles, hard biscuits called *galletas*, and pieces of cloth. They were never admitted inside Don Pedro's house. Occasionally, in the evening, when the

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notes for the day were written, I went out to sit at the Indian camp fires and talk. Usually their group consisted of a cacique, or chief, and six or eight men, who squatted about a small fire. The present of a native cigar to the chief was enough to insure my welcome and give me a seat in their circle, where one boy brewed endless bowls of *yerba maté*, a native tea, and another, perhaps, in a curious, singsong mixture of Spanish and Guaraní (the universal Indian tongue of the Chaco) told the current jungle news in outline—news of a band of rheas in a great savanna, of deer seen near the *riacho*, or of a great breeding colony of white egrets which the Tobas were planning to raid for plumes, and similar important matters. Occasionally an older man wound a bit of grass into a crude baton with which he beat time while he sang in his native tongue, fairly shouting at the beginning, gradually lowering his voice as the song progressed until his breath came in a series of barely audible aspirations, and then raising his voice again to the shouts with which he had begun. Cacique Mayordomo, head chief of the Tobas, whom I had met at Las Palmas, three hundred miles to the southward, had told me not to venture inland from the railroad, as his people of the north were bad. However, they were friendly enough when decently treated, though Argentine soldiers never traveled through this country singly but always in company. Mayordomo seemed to be in disfavor in this section, and the Indians told me that they thought they would kill him when he returned from the south.

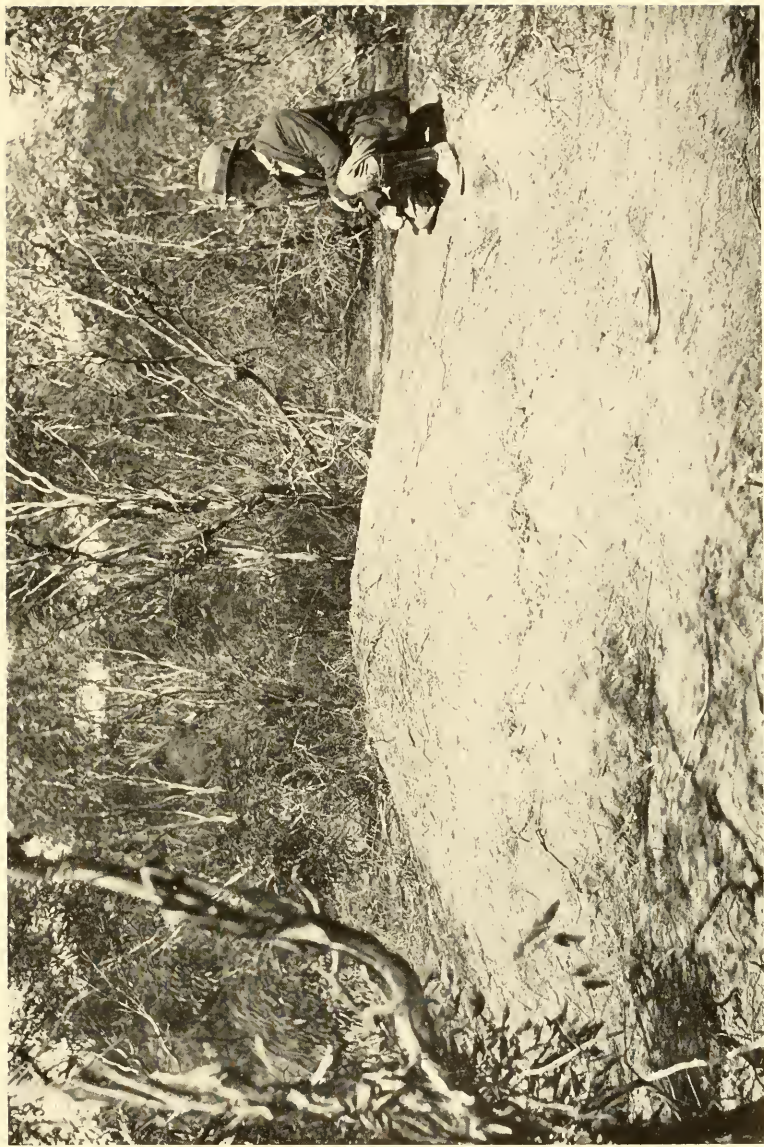
On arrival at the museum, the boxes of specimens are carefully unpacked and the birds entered individually in the museum catalogue and given a museum number, when they are ready for study and identification. Among birds from distant regions it is frequent to find strange and peculiar species that are new to science. When a series of skins of one kind of bird is available, the specimens are assorted according to geographic regions. Such arrange-

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ment usually shows that the extremes in this distribution differ slightly in form, size, or color, so that they may be distinguished as subspecies, typical examples of each subspecies being separated from typical examples of another but connected by a series of gradual changes in specimens from the intermediate geographic area. Skeletons and specimens of birds preserved in alcohol help to establish the relationships of the different groups. The skeletons are also useful in the study of fossil bones. Incidentally, it may be said that the National Museum has now the largest and most complete collection of bird skeletons in the New World, one that is of great importance in scientific studies.

The eggs of birds, also, prove a fruitful source of interesting information. When nests containing eggs are found in the field, great care is taken to identify the species, that there may be no subsequent uncertainty. At camp, hotel, or home, a small hole is drilled carefully in one side of the egg by means of a special egg drill with a fine burr-shaped point, and the contents removed by forcing air into this opening through a slender-pointed blowpipe. When the egg is empty the cavity is rinsed out with water blown in from the mouth through a blowpipe, and the shell is then placed in a bed of fine corn meal, hole down, to drain. Sets of eggs are often accompanied by nests that give much useful information. Aside from the pleasing colors of birds' eggs, there is much to be learned from the structure of the shell and from its appearance and pitting. Collections of eggs form a regular part of the ornithological material in large museums.

Our country recognizes today the great importance of birds in relation to man, and particularly to agriculture. Studies of questions along this line constitute a special branch of investigation known as economic ornithology, in behalf of which prolonged observations are made in the field to determine to what extent birds affect different kinds of crops by eating destructive insects, by pollinating



Nest mound of the mallee fowl (*Leipoa ocellata*) of Australia. Photograph by Charles Barrett



Nest mound of the mallee fowl (*Leipiza ocellata*) partly opened to allow it to be heated by the sun.
Photograph by Charles Barrett

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flowers, or in other ways. For example, certain species of birds occasionally eat cultivated grains or fruits. Before condemning birds wholesale one must first determine what species are doing the damage and then learn whether or not this damage is offset by good done in some other direction. These field observations are checked by prolonged study in the laboratory. Stomachs of birds that have been preserved in alcohol for the purpose are cut open, and the contents are washed out in water and then spread out on little squares of blotting paper and examined carefully under a low-power binocular microscope. The food content is examined bit by bit and assorted, the kinds determined, the amounts of each item estimated in percentages by bulk, and the results recorded on a card. Long experience teaches the trained investigator in this field to identify seeds, insects, bones, feathers, and the other material found. A large series of stomachs taken through the year enables him to build up a picture of the food preferences of the bird in question and to determine whether it is useful or injurious to man. Needless to say this type of investigation constitutes a liberal course in the field of systematic zoology, since almost all kinds of small or moderate-sized plants and animals, in whole or in part, enter into the food of one bird or another and so come to view in these stomachs. In the United States this type of scientific investigation has been developed particularly by the Bureau of Biological Survey of the U. S. Department of Agriculture. A special laboratory force carries on these studies, and the results are used to help frame legislation for the protection of birds.

In laboratories of another type, living birds are used in experiments of various kinds dealing with evolutionary, physiological, or biochemical problems, which need not be enumerated here, since they lie mainly in branches of science other than ornithology.

CHAPTER XI

FOOD AND ECONOMIC RELATIONS

So varied is the food of birds as a group that it includes almost all kinds of animal and vegetable matter of suitable size. Food preferences of the different species range from grass and tender herbage to flowers, nectar, seeds, and grain; from insects, mollusks, and crustaceans to fish, reptiles, and small birds and mammals, to say nothing of decaying flesh. In general, for each variety of food which nature offers in abundance, some bird exists to feed upon it.

Naturally all this diversity of food has had much effect on the external form of birds, particularly on the form of their bills but on that of other parts of the body as well. The woodcock and jacksnipe have long bills with a flexible tip on the upper mandible. These birds probe in soft earth to a depth of several inches to find earthworms, which an ingenious arrangement of the bones of the bill permits them to seize in the bill tip and withdraw for swallowing. The bill of the shoveler duck is broadened and equipped with a series of parallel thin horny plates placed near together. Water and diluted mud, containing small aquatic animals, are drawn into the mouth and then driven out through this strainer, which holds the food and allows the fluid to escape; and the fringed tongue aids the bill in its screening function. The beak of the flamingo, also equipped with a screening arrangement, bends downward abruptly near its middle, and the lower mandible is much larger and heavier than the upper. This seems almost a deformity, but on account of it, when the bird

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lowers its head to feed, the bill comes into a convenient position to serve as a strainer of food from the thin mud which the bird stirs up in the water by treading with its feet.

The wry-billed plover of New Zealand has the tip of the beak bent slightly toward the right to assist it in pulling worms and other animals from beneath the stones of beaches. The bills of grosbeaks are strong and heavy, adapted for cracking seeds to get at the starchy interior. The related crossbills have the sharp tips of the mandibles crossed to twist open hard pine cones and obtain the concealed seeds (see Plate 3, center figure). Curiously enough, some have the mandibles crossed to the right and some to the left. Hawks and owls have sharply hooked beaks for tearing their prey as well as sharp claws for capturing it alive. Herons, flamingos, and many sandpipers possess long legs and long necks so that they may wade in water and feed below the surface. Gallinaceous birds and kiwis have strong claws with which they dig in soft earth to expose their food.

This enumeration of the various special adaptations in birds for the securing of desirable food might be extended for many pages. It appears that bodily form in the different birds, aside from certain definite principles dictated by the requirements of the function of flight, is modified primarily by adaptations for the procuring of food and secondarily by adaptations which aid in sexual display, such as the form and color of feathers.

Vegetable foods constitute the standard diet of many birds and also the reserve diet to which some flesh eaters turn in time of need. Starchy seeds form the most familiar type of vegetable food and are consumed in quantity by a variety of species, from ducks and parrots to sparrows and weaver birds. Many seeds have a hard outer shell that protects the soft, nutritious center. Parrots and sparrows ordinarily crack such seeds one by one, discarding the hulls and shells and swallowing only the

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interior. Ducks, on the contrary, swallow seeds entire, grinding them up in their strong muscular gizzards by means of gravel and sand swallowed for the purpose. And most birds swallow entire small, hard, smooth seeds, like those of amaranth, which are difficult to grip in the beak securely enough to crush.

Starchy seeds play a prominent part in determining the winter range of birds, because they are available from fall until spring in broad areas where the winter climate does not permit activity in insect life. The seed eaters among birds, therefore, are not troubled by the seasonal curtailment of animal food. Plants of many kinds drop their mature seeds to the ground where they lie unnoticed by human eyes but are readily detected by the keener ones of birds. Other plants retain their seeds in the capsules in which they are grown and, as many of the dead stems remain erect, offer a store of food on their higher branchlets. This is a matter of prime importance to the birds when the ground is covered with snow, for it allows many sparrows to remain all the year in regions where snowfall is regular during the winter. Such stores of plant food are of importance also to early migrants, which arrive from the south in spring. In the Great Basin region of the western United States, a rush or tule (*Scirpus paludosus*), sometimes called the "three-square" because of its triangular stem, holds hard-coated seeds in its fruiting tops throughout the long winter and offers them as abundant food for the first arrivals among mallards and related ducks in early spring. These tule seeds are rich in nutriment, and the Indians formerly harvested and ground them into meal for food.

Though many birds that live on seeds in winter turn to an insect diet in summer, some species, like the pigeons, seek starches as food throughout the year. Our common mourning dove subsists on seeds almost exclusively, even in summer, when other food is seemingly more abundant. I have been interested to note that in June, in the eastern

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part of our country, these doves feed extensively on seeds of crane's-bill or wild geranium. Although the plants themselves flower, mature, cast their seeds, and disappear weeks earlier, yet the keen-eyed doves find with ease the tiny pellets of food left scattered on the ground.

The quantities of seeds of all kinds that birds eat annually are beyond expression in figures. Of such small seeds as those of the water primrose (*Jussiaea leptocarpa*), 102,400 have been taken from the stomach and gullet of one mallard duck. In the prairies of eastern Kansas I have seen flocks of Lapland longspurs, small birds of the sparrow family that nest in the Arctic tundras and come south in the fall in great bands to spend the winter, feeding for weeks at a time on fields grown with pigeon grass. As some of these flocks were estimated at over a hundred thousand individuals, they must have consumed enormous quantities of the seeds of this plant. Thirty years ago Prof. F. E. L. Beal estimated that in the State of Iowa tree sparrows alone destroyed 875 tons of weed seeds during the course of one winter. He based this estimate on measured quantities of food found in the stomachs of these sparrows multiplied by the supposed number of the birds in the State. Much credit is due birds for the destruction of weed seed, since the great quantities they eat must play some part in holding these troublesome plants in check. The water-primrose seeds eaten by one mallard, as recorded above, would have been sufficient to seed more than two acres of land with this plant.

The seed-eating habit of birds has at times worked injury to man's interests; for example, where blackbirds and finches have come in great flocks to feed on ripened grains. Only a few species of birds, however, have been concerned in this damage. Years ago, when rice was grown extensively in the southeastern United States, the bobolink, known in its streaked fall and winter dress as a reedbird or ricebird, did serious damage to rice grains while they were still soft and not fully matured. A change in agri-

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cultural conditions has shifted the culture of rice to Arkansas, Louisiana, Texas, and California, outside the range of the bobolink, so that this species no longer figures as injurious. What injury the rice fields now suffer from birds must be charged to red-winged blackbirds. In various places, the mourning and white-winged doves have been charged with the destruction of wheat, but investigation has revealed in most instances that the birds took only waste grain, which had fallen to the ground during harvest and to which they would seem to be entitled. Great flocks of weaver birds in the Sudan have consumed quantities of cultivated grains, so that measures to reduce their number have had to be taken.

Geese feed to a large extent on herbage. In the early years of agriculture in California so enormous were the flocks of geese which fed in the wheat fields in winter that men were regularly hired to drive them out. As the number of birds has decreased, this damage has practically ceased, and it is now claimed by some that the grazing of geese causes the sprouting wheat to stool and so produce more abundantly. Ostriches and rheas feed on leaves and herbage, as do the tinamous to a considerable extent. The spotted tinamou of the South American pampas feeds commonly in fields of alfalfa. The sago pondweed (*Potamogeton pectinatus*) of temperate regions is important as a food for ducks and other herbivorous aquatic birds. It grows submerged in shallow waters, producing an abundant stalk during summer that breaks away in fall and leaves buried in the mud a tasty tuber the size of a kernel of corn. Many species of ducks find in this plant a staple food, eating the tender leaves and stems when they are available and in fall digging great holes in the soft mud to obtain the roots.

Fruits of various kinds offer a summer and fall food supply attractive to many species of birds and one which in dried form is also valuable in winter. As these lines are prepared, a white mulberry tree in the park beneath my

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office window is loaded with an abundant crop of fruit, on which groups of robins, starlings, sparrows, blackbirds, and fish crows feed steadily. Viburnums, dogwoods, wild cherry trees, and many others furnish an abundant supply of easily obtained food to which birds may come from long distances. Often the ornithologist in tropical jungles sees species of birds that he may not have encountered previously during weeks spent in the same region gathered about the ripened fruit of some wild tree. Hackberries, wild grapes, and rose haws dry and remain on the plants throughout the winter, furnishing a store of food for waxwings, mocking birds, grouse, and similar species. The evening grosbeaks feed regularly on the dried keys of the box elder.

Most kinds of herbivorous birds are of medium or large size; but there are a few exceptions, like the palm-chat (*Dulus dominicus*) of Haiti and the Dominican Republic, which eats tender leaves and blossoms with avidity. English sparrows, goldfinches, and pine siskins may in

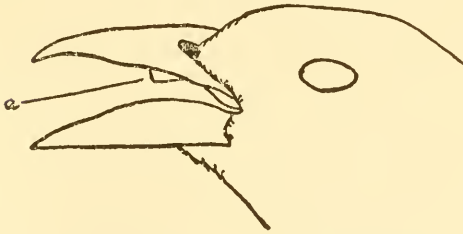


FIG. 5. Head of crow blackbird (*Quiscalus q. quiscula*), drawn with open bill to show palatal keel (*a*), a sharp-edged projection in the roof of the mouth with which the bird cuts open acorns. Drawn by Alexander Wetmore

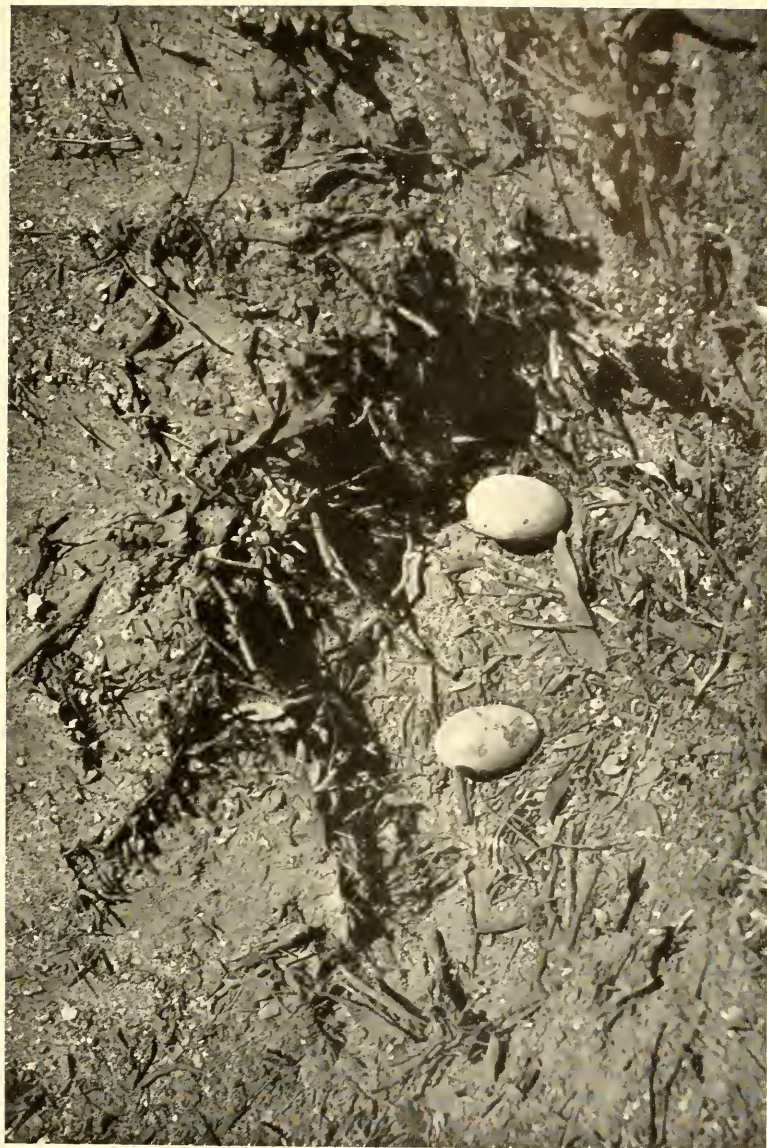
spring consume the new leaves of peas, beets, and similar vegetables, while crows pull sprouting corn for the germinating kernel. Dipping the grain in coal tar before planting will thwart the crow.

Acorns in season constitute the staple diet of many bird species. Jays, particularly, are fond of acorns, holding them between their toes against a limb and splitting open the shell with strong blows of their beaks. The crow

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blackbird, or grackle (Plate 68), feeds extensively in fall on the small acorns—the size of a large pea—of the pin and willow-leaved oaks. The grackle has a thin, projecting plate with a sharp anterior angle in the roof of its mouth (Fig. 5). Acorns are picked up in the bill, pressed firmly against this knifelike edge, released so that they may be turned slightly by means of mandibles and tongue, and then again gripped strongly. In this way the acorn is rotated against the plate until a cut has been made entirely around the shell and the two halves drop off, leaving the meat of the nut in the bird's bill to be swallowed. The mallard and wood duck swallow acorns whole and grind them up in their strong gizzards. These same ducks even swallow hickory nuts whole—with shells so thick that a strong blow of a hammer is required to crack them—and grind them to fragments in their powerfully muscled stomachs to obtain the sweet meat of the interior. The red-headed woodpecker and some of its allies wedge acorns in crevices and holes in tree limbs and then hammer them open with blows from their powerful bills. Besides feeding regularly on acorns in the fall, the red-head frequently stores them for winter consumption, sometimes wedging them in crevices in limbs and sometimes dropping them in holes, where it conceals them under fragments of bark. Most remarkable is the habit of the California woodpecker (*Balanosphyra formicivora bairdi*), a relative of the redhead, which drills holes—each large enough to hold one nut—in the trunks of trees in which it stores acorns for subsequent consumption. There is a record of one tree trunk thus used for storage which was estimated to hold 13,200 acorns, making an average density of sixty acorns to the square foot. This instinct for food storage sometimes goes astray in the woodpeckers, as when they fill the carefully drilled holes with small pebbles instead of nuts.

The pine grosbeak, regularly a vegetable feeder, opens frozen apples in winter to obtain the seeds, discarding the



Eggs of mallee fowl (*Leipoa ocellata*) exposed in their hotbed incubating chamber. Photograph by Charles Barrett

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fruit pulp; and the ruddy quail dove of Porto Rico pecks open oranges decaying on the ground beneath the trees to eat the seeds at their centers. Amazon parrots, which feed extensively on fruits and seeds, swallow small hard seeds which they hold in the stomach and use to grind up other food. Some shore birds utilize hard seeds of rushes for the same purpose. The American woodpeckers of the genus *Sphyrapicus*, known usually as sapsuckers and including the yellow-bellied woodpecker and Williamson's woodpecker, drill elliptical holes in the bark of trees which serve as little reservoirs to gather exuding sap. The birds drink this sap with the aid of the tongue, which has a brushy tip instead of the hard-pointed spear found in other woodpeckers. They tap many kinds of trees, most commonly, in the eastern United States, the apple, particularly in partly abandoned orchards, and the hard maple. Old apple trees frequently have the bark completely covered with woodpeckers' punctures, spaced only a short distance apart.

Humming birds (Plate 52) feed extensively on the nectar of flowers. They secure this by means of the long tongue, which for part of its length has the edges rolled to form a tube. Most species have long bills—reaching from four to six inches in some South American forms—which they use in probing flowers. In some species the bill is bent in a pronounced curve. The amount of nectar consumed by an individual is difficult to ascertain, but it is probably considerable. Miss Althea Sherman records that ruby-throated hummers that came to feed in her yard took sugar water daily in such quantities that the sugar consumed weighed twice as much as the bird. It may be noted that hummers, while taking nectar, also consume quantities of flies and small spiders and Hymenoptera, so that animal food plays an important part in their fare.

Animal food forms the staple sustenance of large numbers of birds. It includes mammals and even other birds. Species that are regularly vegetarian when adult frequently

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require animal food when young. Many sparrows feed their young largely on insects. Ducklings also take animal fare in large amount. Even pigeons, which when grown eat only vegetable food, feed their small young on an animal product formed in the bodies of the parents. This "pigeon's milk" is a curdlike substance formed in the walls of the crop of both parents by the sloughing off of rapidly growing cells and is regurgitated for feeding to the young squabs.

Insects make an abundant and easily obtained food for many hundreds of species of small and medium-sized birds, some of which depend entirely upon them and others of which utilize them only in the warmer part of the year, turning to seeds or other vegetable food in fall and winter. Flycatchers watch for flying insects and dart out to seize them with a loud snap of the bill. Swallows and swifts course through the air, seizing their winged prey in their broad mouths as they fly. This last method of food capture attains its highest development in the nighthawks, whippoorwills, and other goatsuckers, which have very broad mouths that serve as veritable nets to capture insect prey. Several thousand flying insects of more than fifty species have been taken from the stomach of a single nighthawk. The mouth of the chuck-will's-widow, a nocturnal species of the goatsucker family found in the southeastern United States, extends back beneath the eyes and measures more than an inch and a half from corner to corner. When the bill is opened the aperture expands even more, so that the bird can engulf large moths with ease and has been known to swallow wood warblers and other small birds. The frogmouth of Australia (*Podargus*) is even more grotesque, as large specimens measure two and a half inches across the mouth. Birds of this nocturnal group have very large eyes, and the outline of the eyeball may be seen through the thin, semitransparent membranes covering the roof of the mouth. Years ago some naturalists supposed that frog-

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mouths directed their capture of insects by rolling the eyes inward so that they peered out through the mouth membranes! Acrimonious debate on the subject continued in one of the scientific magazines for several years, until finally the opposition proved that such extraordinary rotation of the eyes was impossible.

Such birds as the wood warblers, vireos, white-eyes, and Old World warblers search through foliage for insect prey, seizing it expertly from the twigs and leaves or tumbling pell-mell after some moth that attempts to escape by flight. Aphids are the particular prey of birds of this type, and smooth caterpillars of various kinds are prized tidbits. The yellow-billed and black-billed cuckoos of America have a predilection for hairy caterpillars, particularly webworms, and destroy them in large numbers. The stomach lining of these birds becomes so filled with the spiny hairs of their fuzzy prey that it appears to be grown with closely set fur.

Cowbirds follow grazing cattle in the pastures, often perching familiarly on their backs, to secure grasshoppers and other insects which are stirred out of the grass by the movements of the mammals. The black witch, or ani, a cuckoo with peculiarly compressed bill and long tail found in tropical America, has a similar habit. The ani is supposed also to eat ticks that it picks from the skin of domestic stock, but this habit seems more common in some species of blackbirds than in the black witch.

The starling feeds at times by thrusting its pointed bill in soft ground and then forcing the tips of the mandibles apart by means of a peculiar lever arrangement in the articulation of the lower jaw, where a slender bar of bone projects behind the joint, with strong muscles extending from this bar to attach to the side of the skull above. Contraction of these muscles acts on the bar so that it forces the halves of the bill tip apart, permitting the bird to seize grubs and worms. Some orioles have a similar

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development by means of which they explore rolls of leaves for hidden larvae.

Ants are eaten by many birds, particularly by some of the woodpeckers. The flicker feeds on ground-living ants. It opens their hills and with its long tongue, which is covered with a sticky secretion, licks the insects into its mouth as they scurry hastily about. One flicker examined had five thousand and forty ants in its stomach. The pileated woodpecker chisels open ant-infested dead wood in the trunks of trees and so secures its prey. Woodpeckers' mouths have very large salivary glands, which secrete an abundance of alkaline fluid. It has been suggested that this alkaline saliva serves to neutralize the formic acid of the ants eaten so abundantly by some members of the woodpecker tribe.

The hairy and downy woodpeckers feed extensively on wood-boring larvae, which are highly destructive to trees. They cut such prey out of dead wood and even out of wood as hard as that in oaks. I have seen borings of the hairy woodpecker made through an inch of solid oak to the tunnel of a beetle larva. When the tunnel is reached, the bird spears the grub on the horny end of its protractile tongue, which may be extended three inches or more beyond the tip of the bill. Spiders and insects hibernating in or under masses of leaves and in crevices in bark, as well as insect eggs, contribute largely to the winter food supply of a few birds, such as the Carolina wrens, chickadees, and kinglets, which brave the severe cold of winter in the north. Such elimination of destructive insects and their eggs before the coming of spring cuts down mightily their potentiality for damage to agriculture the following season.

Wherever insects of any kind become abundant many species of birds turn to feed upon them. Outbreaks of tussock-moth caterpillars attract the notice of house sparrows, robins, catbirds, and many other birds that normally pay little attention to hairy caterpillars. Unusual swarms of insects like grasshoppers, which are highly

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desirable as food, draw many kinds of birds to feed upon them—from hawks, crows, and gulls, to killdeer, horned larks and herons—and suffer tremendous destruction as a result. Thus birds aid appreciably in keeping insect pests under control.

Earthworms make up a substantial part of the food of a number of birds. The common robin seizes them expertly and draws them from the earth; crow blackbirds and woodcock are also partial to the same food; and water thrushes overturn leaves to secure small earthworms. I have seen a red-headed woodpecker watch a robin until the latter had drawn a worm from the earth and then dart down and seize the food before the robin could swallow it. House sparrows also parasitize robins in the same way to some extent.

Starlings eat millipedes in abundance, many shore-living sandpipers take nereids or sea worms, and mollusks are frequently a favored prey for birds. The scoters, heavy-bodied ducks not particularly desirable for human food, swallow oysters and clams entire, breaking them in their gizzards and grinding shell and animal to fragments. Gulls, rooks, and crows fly aloft with clams in their bills, drop them from a height on stones below, and so break them open to obtain the meat. Crustaceans also constitute an important source of food for many birds. The barred owl feeds regularly on crayfish. Herons and kingfishers eat great quantities of fiddler crabs and crayfish, doing considerable good in lowland fields in the South by their destruction of the latter. The abundant amphipods of northern waters make excellent food for plovers, sandpipers and other birds, as do the mole crabs (*Hippa talpoides*) of our sandy beaches. In lake waters of high salinity, like those of Great Salt Lake, Utah, the fairy brine shrimp swarms in incredible abundance and furnishes a much sought food for ducks, phalaropes, and sandpipers.

Of the larger creatures which serve as food for birds, fish stand first, constituting the principal source of nour-

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ishment for large numbers. Pelicans have great pouches of pliant skin beneath their beaks which they use as scoops in making their catch. The brown pelican fishes by diving, flying about at an elevation of thirty to sixty feet above the surface and plunging swiftly into the water at the sight of a fish. White pelicans swim in long lines, beating the water with their wings and scooping with open bills at small fish driven in schools ahead of them. Cormorants, loons, grebes, snakebirds, and mergansers prefer to dive for their meals; while herons and bitterns stand quietly until fish rise within reach, when they transfix them by a lightning stab of the pointed beak. The black-crowned night heron regularly watches from stakes or logs over deep water, and springs in headforemost to get fish just beyond its reach. Terns and kingfishers strike at small fish from the air, as do boobies and gannets.

Charges of far-reaching injury to industrial fisheries have been made against fish-eating birds, but in the majority of instances cited they have not had much to substantiate them. For example, brown pelicans in Florida have been blamed for the decreasing return of the mullet fisheries. I have found from personal observation, however, that the pelican is seldom able to capture the agile mullet except in those rare instances when it encounters an injured fish. In fact, on the east coast of Florida the pelican's food consists in the main of menhaden, a fish which is valuable principally for fertilizer and which swarms in such tremendous schools that the few individuals taken by pelicans amount practically to nothing.

It must be freely admitted, however, that herons and mergansers catch trout along inland streams; but unless the birds become too numerous—though with this statement the ardent fisherman may not agree—some consideration should be given to the ethics of a situation in which the birds in question have fed for centuries on the fish before man came to compete with them and the fish supply decreased. Fishermen naturally have certain rights to the

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protection of their sport; but so also have the equally numerous bird lovers, who derive as much mental stimulation and delight from the sight of a graceful heron flying from a trout-filled pool as does the angler from examination of a well-filled creel. The destruction of herons, grebes, and kingfishers that frequent the breeding ponds of fish hatcheries is justified, as unquestionably they will destroy valuable fish. But elsewhere it may be questioned whether the birds do not have vested right in a small part, at least, of the fish of our waters.

Fish-eating birds have in some places proved of great economic importance because of the accumulations of guano, valuable as a fertilizer, in their rookeries. Guano deposits have been found on many oceanic islands where albatrosses, terns, boobies, and shearwaters nest in abundance; but the most famous deposits occur on the coastal islands of Peru, where pelicans, cormorants, and boobies have nested for unknown hundreds of years. So numerous are these birds that they blacken the surface of entire islands when at rest, and when in search of fish their great flocks, flying in long lines, may take several hours to pass a given point. It has been estimated that ten million tons of guano were removed from the Chincha Islands between 1851 and 1872, and the birds responsible for it have been rightly termed billion-dollar birds. The Incas, before the discovery of America, recognized their value and protected them carefully; but modern man followed a ruthless course and almost exterminated them. Only recently, following careful studies, have adequate measures of protection been instituted, insuring the continued production of guano.

Frogs and salamanders form regular prey of herons and other aquatic birds; and certain abundant small arboreal frogs of tropical America are eaten by many birds, from tiny todies and vireos to hawks and barn owls. A number of birds, such as small hawks, shrikes, and several large cuckoos, including the road runner and the lizard cuckoo

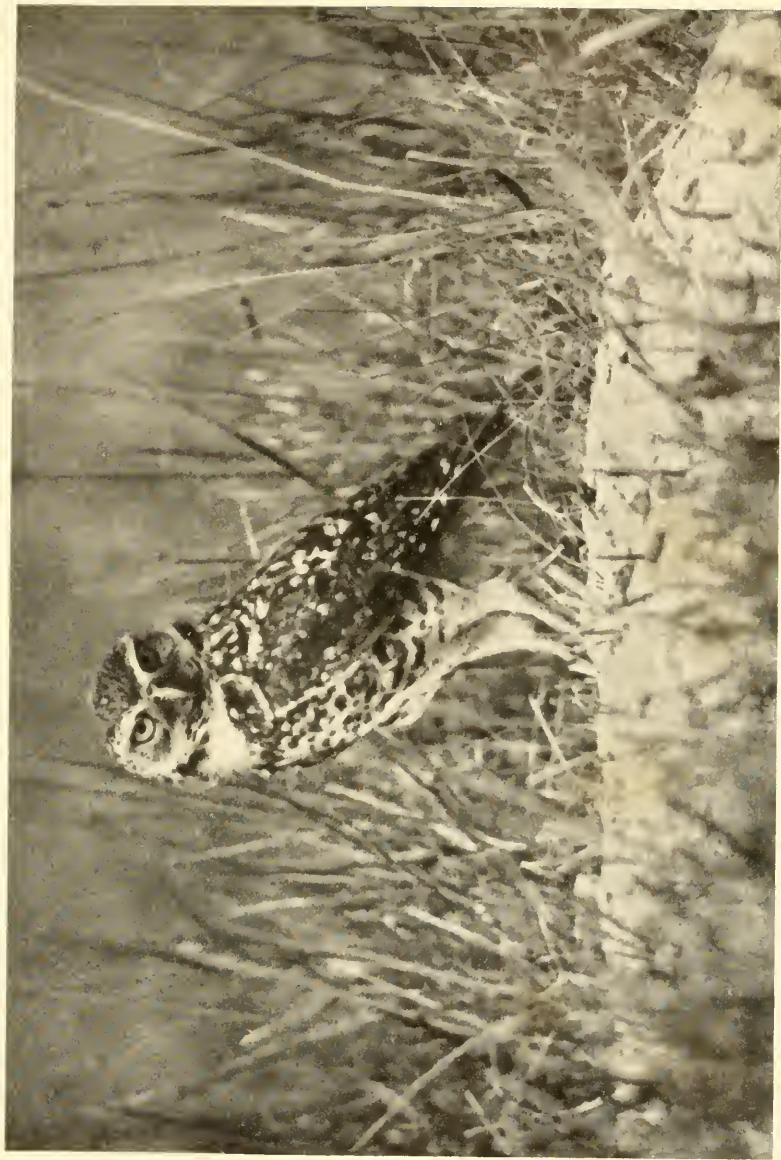
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of the West Indies, consume lizards and snakes in great quantity. A burrowing owl (Plate 60) that I once had as a pet delighted in capturing and eating garter snakes, killing them by biting and then swallowing them head-foremost. As the owl was small, it could not ordinarily complete the swallowing of the snake until the first section had been partly digested, so that after such a meal it stood about for an hour or more with the tail of the snake hanging from the corner of its bill. The secretary bird of Africa, a hawklike bird that runs on tremendously elongated legs, kills snakes by stamping on their heads with its hard toes until it renders them helpless. Crows capture small mud turtles, particularly in spring when they are emerging from their hibernation, and pull out the meat from between the openings in the shell.

The bearded vulture, a species with a magnificent spread of wings that ranges from the mountains of Portugal to China, is said to carry turtles aloft in order to drop them on hard surfaces and so break them into bits that may be swallowed. According to the account of Pliny, the Greek poet Aeschylus (who died in 456 B.C.) is said to have met a tragic death when one of these vultures, mistaking his bald head for a stone, dropped a tortoise on it from high in the air. The bald among our readers may do well to consider the distribution of this bird and use care in baring their heads when within the danger zone of its range!

Such predacious birds as hawks and owls eat other birds of various kinds. A few species subsist principally on such prey. Large owls have been known to eat small owls, and large hawks to pursue and kill smaller ones. Jays, crows, grackles, starlings, and magpies eat many small young of other species of birds, being accused at times of considerable damage in pursuit of this bent.

Small mammals also constitute a staple source of food for many hawks and owls. Most of these fine birds do enough good in the destruction of injurious mice and rats



Florida burrowing owl (*Speotyto cunicularia floridana*). The burrowing owls found in America live in holes in the ground. Photograph by Dr. Arthur A. Allen



Decoy canvasback duck made by prehistoric Indians in Nevada, used in hunting. After Loud and Harrington

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to more than atone for the useful birds or the occasional domestic chicken with which they make away. Misguided campaigns against the larger hawks and owls have greatly decreased their numbers in many sections of the United States, with the result that depredations of wild mice in orchards and fields have begun to arouse serious complaint. Many thousands of dollars are expended annually in the attempt to destroy these pests by poisons and otherwise, work that hawks and owls did formerly without recompense other than their food. The great horned owl, the goshawk, the Cooper's hawk, and the sharp-shinned hawk destroy birds of all kinds, including game birds and domestic fowl, and need to be kept in check. To the average irate agriculturist or sportsman, a hawk is a hawk and an owl is an owl, so that the sins of the few species mentioned have been visited on their host of relatives—the red-tailed, red-shouldered, and rough-legged hawks, and the barred and barn owls, which are not only harmless but distinctly benefit man in feeding extensively on creatures inimical to his interests.

The food of the barn owl illustrates how beneficial these species can be. Like other hawks and owls this bird tears its prey apart and swallows the pieces entire. In the course of digestion the flesh is assimilated, while bones, fur, feathers, and other indigestible portions are formed into a compact pellet, which at the proper time is regurgitated, leaving the stomach empty for another meal. Such pellets accumulate beneath the day roosts of these owls, and identification of the bones they contain teaches us the food predilections of the devouring bird. Since the days of Joseph Henry, first Secretary of the Smithsonian Institution, barn owls have inhabited the northwest tower of the Smithsonian building, annually rearing their families in this secure retreat. From 1,247 of their regurgitated pellets, collected on the tower floor, there have been taken the bones of 1,987 field mice, 656 house mice, 210 rats, 92 sparrows and blackbirds, and

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4 frogs. These figures definitely indicate that this owl is useful in its destruction of harmful rodents. For twelve consecutive months I visited these owls in the tower every thirty days to collect the accumulated pellets; and I found that the birds they had eaten were secured principally in summer, when many unwary young were about, while in winter they got many house sparrows which gather nightly at this season in great roosts in the trees on Pennsylvania Avenue near by. Curiously enough, I found occasional skulls of the harvest mouse (*Reithrodontomys*), which is so rare in the vicinity of Washington that much of our knowledge of its occurrence there rests on specimens taken from barn owl pellets in this tower. Collections of pellets of the barn owl that have come from southern California have contained hundreds of skulls of pocket gophers which are highly destructive in the cultivated fields in that State. These birds should be protected.

The last type of food we shall mention is carrion, sought by certain highly specialized birds. Vultures sometimes take freshly dead flesh, and again feed on putrefying bodies in such condition that disgust at the filthy habit is overcome in the thoughtful by wonder at the bird's absolute immunity to the ptomaines which putrefactive bacteria generate and which are so dangerous to man. The turkey vulture and the black vulture are the common birds of this group in America. In general, species with such food preferences are found principally in areas where large mammals abound, the bodies of which furnish the scavengers with a regular supply of nutriment.

CHAPTER XII

THE KINDS OF BIRDS IN BRIEF REVIEW

At the present time approximately 25,000 different kinds of birds are recognized in the entire world, of which about 800 are fossil forms. All are classified according to a scheme that tries to bring together related groups. Attempts at such a scientific classification have been multitudinous and various. The method in general use at present originated with Carolus Linnaeus of Sweden, who, in 1758, proposed that each species be designated by two names, generally in Latin form: The first, the genus name, applying usually to a number of somewhat similar, allied forms; and the second, the species name, applying to one form only within the genus with which it is used. Sometimes a third name is added to distinguish what is known as a subspecies, which differs slightly in color, size, or form from members of the same species in other parts of its geographic range. Finally, in formal lists, the Latin scientific name is followed by the name of the authority who first named the species or subspecies. As an example, the accepted scientific name of the osprey or fish hawk of North America is *Pandion haliaëtus carolinensis* (Gmelin), which has all of the elements above defined.

Species are grouped in genera; genera of similar kind are united in subfamilies and families; families are combined in suborders and orders. In accordance with modern understanding of the birds of the world today I have grouped the known kinds in thirty-three orders, of which six include fossil forms only and twenty-seven have both fossil and living species. A brief review of these orders follows.

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The first order to be mentioned (*Archaeopterygiformes*) includes the oldest known fossil birds, which vary widely in form from birds existing today. The two genera of this order (*Archaeopteryx* and *Archaeornis*), of the Jurassic beds of Bavaria, have already been sufficiently described (see pages 41-43). They are so primitive that they are separated sharply in the classification scheme from all other birds, being placed in the subclass *Archaeornithes*, while all others are ranked in the subclass *Neornithes*.

The next two orders, also, contain fossil species only, known from the Cretaceous beds of North America, and are likewise represented by birds with teeth. These two orders are quite distinct from each other: the members of one (*Hesperornithiformes*) are large, formed like diving birds (see Plates 16 and 17), and entirely flightless; and the members of the other (*Ichthyornithiformes*) are the size of a domestic pigeon (see Plate 20), with powers of flight well developed. Because of their teeth and other peculiarities these two orders (see pages 43-45) are set off sharply from the remaining kinds of birds, making the superorder *Odontognathae*.

The group of living birds placed lowest in the scale of classification is that of the ostriches (order *Struthioniformes*), which range from southern Palestine and Arabia through the Sudan to southern Africa. All ostriches are grouped in a single species, with five subspecies through this vast range. Ostriches have the distinction of being the largest of living birds. They represent a very ancient type, and are highly specialized for a purely terrestrial life, being entirely flightless and having only two toes on each foot. They run with great rapidity. We find figures and inscriptions of them in ancient cities and mention of them in the Bible. Ostriches inhabit arid sections mainly and penetrate regularly in little bands into the open wastes of the African deserts. They are polygamous, each male having from three to five mates. The eggs are laid in a communal nest, which is merely an unlined hollow



Female frigate bird (*Fregata minor strumosa*) with nest and young. Necker Island, Hawaiian Bird Reservation. Photograph by Alexander Wetmore. Courtesy of the Bureau of Biological Survey



Canvasback duck (*Nyroca valisineria*), a typical diving duck, with heavy, compact body and large, broadly webbed feet, placed far back.
Photograph by Dr. Arthur A. Allen

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scratched in sand, and are tended principally by the male during incubation. For a time ostriches were domesticated in large numbers for the sake of their plumes, which milliners used to dress ladies' hats. But changing fashion has abandoned these plumes, to the injury of the thriving ostrich farms in the United States. More recently tanned ostrich hide has enjoyed a considerable vogue for leather novelties of various kinds.

The rheas (order Rheiformes), sometimes called the American ostriches, are flightless birds of smaller size found in the open pampas of South America. They differ from the true ostrich in having three toes and in a number of other anatomical peculiarities. Rheas are divided into three species: The comon rhea, with several geographic races, which range from northeastern Brazil south into Argentina; Darwin's rhea, found in Patagonia; and a third, much smaller species that occurs in the high altitudes of the Andes from the province of Mendoza (Argentina) to Bolivia. The rheas range in bands in quest of food over plains or in areas of open brush. Several females lay together, and a single nest will sometimes contain from thirty to sixty eggs. The male alone incubates the eggs and cares for the young. Small rheas make amusing pets and accept human companionship with entire trustfulness. One that I had for a time in Paraguay walked with very erect carriage and presented a preternaturally mature appearance, which was betrayed, however, by its constant stumbling over the slightest obstacle. It came readily in response to an imitation of its mournful-toned whistle, and spent long hours reclining contentedly across my feet and ankles as I worked on specimens or notes. Like some other pets, a baby rhea grows with surprising rapidity and may soon become a nuisance because of its omnivorous appetite, which is satisfied with anything small enough to swallow, from the vegetables intended for dinner, seized instantly when the cook is not looking, to the watch or shaving soap of the unfortunate owner. Rheas still remain common

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where land is held in large tracts; but their numbers are decreasing in the more fertile sections of the central pampas of Argentina, since they are destructive to small crops and except for their feathers, which are used in making feather dusters, have little commercial value.

Another group of large flightless birds (order Casuariiformes) includes the cassowaries and emus. The cassowaries (family Casuariidae) are confined to New Guinea and near-by islands, and to northern Queensland, Australia. At present we recognize sixteen species and a considerable number of geographic races or subspecies, so that cassowaries are much more numerous in kind than the other large flightless birds. They are characterized by a peculiar horny casque, or helmet, on the head, by five or six long, bare, black quills that represent the wing feathers, and by very strong feet and legs. The bare skin of the head and neck of adults, during life, is variegated with brilliant colors. The cassowaries inhabit forests, differing in this from the groups closely related to them. Each female has her own nest, which is placed on the ground. She lays from five to eight eggs, which have a coarsely granulated surface.

The emus (family Dromiciidae) are confined to Australia, where a single species ranges through most of the continent and formerly extended to Tasmania. Another species, now extinct, was found formerly on Kangaroo Island, off the coast of South Australia. Several fossil forms have been described from Pleistocene deposits. Emus swim well and have been seen crossing large rivers. They differ from the ostriches and rheas in being strictly monogamous. The nest is a hollow scratched in the earth, and where vegetation is abundant it is lined with herbage. The eggs are a beautiful dark green with a coarsely granulated shell that is very rough. The Australian aborigines ate both the eggs and flesh of the emu, but the flesh is said to be too rank to be palatable to Europeans.

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The moas (order Dinornithiformes) of New Zealand constitute another order of birds, now extinct. They were related to the kiwis, were flightless, and, in fact, so far as known, had no wings whatever, since in all the multitudinous remains of them that have been discovered no wing bones of any kind have been found. They have been described already (see pages 47-48).

The elephant birds (order Aepyornithiformes) of Madagascar make up still another group of extinct flightless birds. For a description of the elephant bird see page 47.

The kiwis (order Apterygiformes), comprising three species with several additional races, are confined to New Zealand, where they still exist in spite of colonization, though in reduced numbers. They are among the most peculiar of existing birds—flightless, and possessed of a long bill at the very tip of which are the nostrils. The body is covered with bristly feathers that resemble hairs, the legs and feet are very heavy and strong, and the wing is reduced to a vestigial organ only about three inches long, though the bird is as large as a domestic fowl. Kiwis inhabit forests and are active only at night, as they have defective vision. They feed extensively upon earthworms.

The tinamous (order Tinamiformes), found principally in South America but extending north into southern Mexico, are related in structure to the preceding orders from the ostriches to the kiwis, all these together forming the superorder Palaeognathae. The tinamous differ from all the others in this superorder in possessing the power of flight, which, however, they seldom voluntarily exercise, as they are preferably terrestrial in habit. Numerous species of tinamou exist, and the order is divided by choice of habitat into two principal groups, one of which inhabits dense forests and the other open areas. In appearance tinamous resemble quail and grouse but are not closely allied to these groups. The remarkable and beautiful colors of their eggs have been already described (see page 81). Some of the South American forms, par-

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ticularly the spotted tinamou, make excellent game. They fly swiftly, and they leave the ground with a roar of wings that is highly disconcerting to the nerves of the hunter. They alight awkwardly, frequently falling over, and are so exhausted by their flight that they usually skulk and hide rather than fly again. In the past few years large cold-storage shipments of spotted, rufous-winged, and crested tinamou have come to the United States from Argentina and Uruguay, and have been served regularly in our restaurants under the name of "South American quail."

With the next order of birds, the penguins (order Sphenisciformes), there begins the final major group of birds (superorder Neognathae) which includes all other living forms. The twenty or more living species of penguins are confined to the Southern Hemisphere, mainly to the Antarctic regions, although two species occur along the coasts of South America and one is found on the Galápagos Islands. Strangely enough, penguins seem always to have had this southern range and have never extended north beyond the Equator. Although numerous fossil species are known, dating back to the Miocene (some from strata now classed as Eocene, but in my opinion probably of later date), yet all the forms at present known have been found only in the far south.

In many ways penguins are the most peculiar in form of living birds. They are aquatic, seeking their food in the sea, and have the wings modified into flat, compact organs like the flippers of a seal, without projecting feathers. With these they "fly" swiftly through the water, the feet extended behind and serving as a rudder. Short, stiff feathers cover the body evenly, without a break. During the molt the feather covering sloughs off in irregular patches, as does a lizard's skin when it is shed. The wing bones are shortened, flattened, and stiffened, and the tarsus is very short. The birds stand as erect as men. Some species nest singly, while others gather

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in great colonies to breed. The king penguin holds its egg during incubation in a fold of skin on the abdomen. One species on the Falkland Islands nests in burrows which it excavates in the ground. Other species lay their eggs in natural depressions in the earth. The little blue penguin (*Eudyptula minor*) of southern Australia, New Zealand, and the near-by Chatham Islands measures barely sixteen inches in length, while the great emperor penguin (*Aptenodytes forsteri*) reaches four feet.

The loons (order Gaviiformes) comprise five distinct species of aquatic birds, peculiar to the Northern Hemisphere and of large size, ranging from twenty-four to thirty-eight inches in length. The birds are long and heavy of body; they have broad, webbed feet located far back and relatively small wings. They secure their food, which consists of fish and other aquatic animals, by diving, and can descend to considerable depths. They move with difficulty on land, but in the water they are graceful and active. If there is no breeze to assist them, they find it hard to rise on the wing, but once in the air they fly swiftly. In the air they present a peculiar appearance because of the projecting head and feet and the small size of the rapidly moving wings. The adult common loon (*Gavia immer*) measures nearly three feet in length; the back and outside of the wings are black-barred and spotted with white, while the head and neck are glossed with violet-green (see Plate 37). The bird has a melancholy, laughing cry that is well known throughout its haunts. It nests in inland lakes, laying two large, deep-brown eggs on a nest built up at the edge of the water. The young swim at birth and follow the parents immediately into the water. The yellow-billed loon (*Gavia adamsi*) is a close relation, and the remaining species, of smaller size, include the black-throated (*Gavia arctica*), red-throated (*Gavia lumme*), and Pacific (*Gavia pacifica*) loons.

The grebes (order Colymbiformes) are smaller than

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loons, with similar habits but differing considerably in structure. The feet are lobed instead of webbed, and the tail appears to be absent, due to the fact that it is composed of such loose plumes that it is not easily distinguished. About thirty known species are distributed throughout the world. All nest in fresh water, but some species migrate to the coasts to frequent salt water for a period after nesting. Grebes live exclusively in the water, and are even more expert in that element than loons. Ordinarily they dive to escape danger, often sinking slowly beneath the surface as though pulled down by some invisible hand, but when greatly startled they disappear with astonishing celerity. They disappear so rapidly at the flash of the discharge of a gun that they are usually safely beneath the surface of the water before the shot can reach them. Once below, they swim away under the water, thrusting the bill above the surface when they need to breathe, until they are safe in the shelter of rushes. These diving powers have earned for grebes the appellations of water witch, hell-diver, and didapper.

Grebes feed on fish, crustaceans, larvae of aquatic insects, and land insects that they find floating on the surface of the water. With each meal they stuff the stomach with feathers from their own bodies, which are ground up and digested with their food. The reason for this habit is still obscure. The powerfully muscled legs of grebes, like those of loons, are placed far back on the body. They move with difficulty on land and only venture ashore occasionally to rest in the sun at the edge of the water. Even their nests are masses of vegetation that float in the water (see Plate 36). In spite of their small wings, grebes, with the exception of one form, resident on Lake Titicaca, Peru, can fly.

The albatrosses, shearwaters, fulmars, petrels, and diving petrels (order Procellariiformes) are essentially pelagic in range, coming to land only for the period of nesting. In all of them the nostrils open externally through short,

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horny tubes, which may serve to protect their breathing from blowing spray during storms. Some of the numerous kinds of great albatrosses are, like the smaller petrels, familiar sights in the wake of ocean liners. The sooty albatross, in particular, regularly follows steamers that cross the North Pacific. The larger species of the Southern Hemisphere, such as the wandering albatross (*Diomedea exulans*) and its relatives, have a maximum wing expanse of eleven feet four inches. They all have long narrow wings, by means of which, without flapping them, they glide against air currents hour after hour—a marvelous performance at which the observer never ceases to wonder. The helplessness of these birds in a calm atmosphere restricts them to latitudes of steady sea winds.

Albatrosses resort to small oceanic islands to nest, congregating in colonies that often contain thousands of individuals. Their mating is accompanied by strange dances, in which the birds go through regular motions and contortions, shaking their heads, rattling their bills, stepping about, bowing, and so on. These actions are more than a mere mating display, as they are continued during the period of incubation and care of the young. Among the best known nesting colonies of these birds are those of the Laysan albatross (*Diomedea immutabilis*), on the Leeward Islands of Hawaii (see Plate 47). These islands are now included in the Hawaiian Bird Reservation, a fortunate circumstance, as the birds in former years were subject to unwarranted destruction for their plumes. Shearwaters, which are larger than the tiny petrels, nest also in great companies (see Plate 29). The diving petrels (family Pelecanoididae), which inhabit the southern seas, have become modified so that they pursue their food and escape their enemies by swimming with amazing ease beneath the waves.

The families of tropic birds, pelicans, boobies, cormorants, snakebirds, and frigate birds (order Pelecaniformes) have as a common external character the exten-

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sion of the webbing of the feet across all four toes. They also have several internal anatomical resemblances. Superficially the tropic birds (family Phaëthontidae) resemble gulls; but they have one or two feathers of the tail projecting far beyond the others, and these flutter gracefully when the birds are in flight. The pelicans (family Pelecanidae) are divided into a salt-water group, grayish-brown in color, that secure their food by diving (see Plate 48), and a fresh-water group, with plumage partly or entirely white, that fish by using the pouch as a scoop or seine. The white pelican of North America (*Pelecanus erythrorhynchos*) develops in the early spring a narrow keel two or three inches high and equally long on the center of the upper mandible. This curious ornament is kept until June, when it is shed, to be replaced the following year.

The boobies (family Sulidae) (see Plate 42), the cormorants (family Phalacrocoracidae), and snakebirds (family Anhingidae) all fish by diving. The frigate birds (family Fregatidae), of which the largest species has a wing spread of six or seven feet (Plate 62), are pirates and subsist principally on food taken from other bird fishermen. I have frequently seen two frigate birds pursue a shearwater or booby bound to its nest from a fishing excursion. They kept relentlessly above the luckless bird and, if it proved recalcitrant, struck at it until it disgorged the contents of its stomach, which the robbers seized expertly in the air.

The herons, shoebills, storks, ibises, and flamingos (order Ciconiiformes) compose a considerable group of long-legged and long-necked wading birds. In many countries herons are considered game and are shot for food, but this is not common in the United States. I have known great blue herons to swallow young coots, half-grown domestic kittens, and muskrats, and in the Western States they come regularly to watch for pocket gophers in cultivated fields. The little blue heron (see Plate 30) frequently renders important service in the West Indies by destroying

PLATE 64



Group of canvasback ducks (*Nyroca calisineria*) swimming. In the water these birds present a much more graceful appearance than on land. (See Plate 63.) Photograph by Dr. Arthur A. Allen



Virginia rail (*Rallus virginianus*), a common species of North America. Rails are marsh-inhabiting birds, with long legs and necks and slenderly compressed bodies. Photograph by Dr. Arthur A. Allen

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grasshoppers in dry fields. The white stork is a well-known bird in northern and central Europe, where it builds its nest familiarly on housetops and about towns. It is considered a bird of good fortune, for which reason it escapes molestation. Numbers of other kinds of storks less well known are scattered through the world. The ibises, inhabitants of marshes and swamps, have long, curved bills, but otherwise they are heronlike in appearance. The spoonbills are ibises with the tip of the bill, which is from one and a half to two inches wide, flattened so that it resembles a spatula.

The flamingos resemble ducks in certain points, in spite of their quite different form. Several species occur in America and the Old World, all similar in general appearance, with long, slender legs, long necks, beaks bent abruptly down near the middle, and plumage tinged more or less with rose. Most species build a pillar of mud for a nest, placing the eggs in a depression on the top, where they are safe from fluctuating water levels over the mud flats on which they are located. The birds incubate by folding the legs beneath the body—not, as the old superstition has it, by straddling their mud turrets. They nest in colonies. Though we generally think of flamingos as tropical birds, there is one species that nests in southern Patagonia and in lakes in the Andes more than ten thousand feet above sea level, where the weather is cold and often stormy. Great colonies nest on certain lakes in the Andes of Bolivia, where men collect their eggs by the thousands, roast them slightly to preserve them, and then transport them to the lowlands to sell.

The screamers and the ducks, geese, and swans (order Anseriformes) comprise the next major group. The screamers (family Anhimidae), which derive their name from their loud calls, are confined to South America. Their chief peculiarities are two long, knifelike spurs at the bend of each wing and the masses of air cells, connected with the lungs, that lie between the skin and the

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flesh of their bodies. The crested screamer of Argentina and adjacent countries equals a small turkey in size and has very long toes, which enable it to walk about in bogs and swamps. This bird rises in the air and wheels for hours on motionless pinions, like a vulture. Ducks, geese, and swans (family Anatidae) are world-wide in distribution. Swans maintain their numbers with some difficulty; but ducks and geese, with reasonable protection, remain abundant in spite of decrease in suitable range due to the drainage of their native marshes and swamps. Geese make model parents, the male guarding the female during incubation and assisting subsequently in the care of the young. The family Anatidae displays considerable variety of form, from the great long-necked swans to the tiny teal (Plates 63 and 64). It includes a number of specialized types, such as the mergansers, with narrow, serrate-margined bills adapted for the capture of fish, the diving ducks, and the torrent ducks of South America, which are built like mergansers and which live in the swiftest streams.

The vultures, hawks, and falcons (order Falconiformes) are divided into two principal groups, the first of which contains the turkey, king, and black vultures and the condors (suborder Cathartae) of the New World. Both the California and South American condors have a wing expanse ranging from eight feet six inches to nine feet ten and a half inches, but the other vultures are smaller. The heads of the birds in this first principal group are bare, and the skin thereof is more or less brightly colored. Vultures are primarily scavengers, feeding on carcasses of decaying animals, though the condors are said to attack the helpless young of various animals.

The other principal group into which the order Falconiformes is divided includes three distinct families. The most peculiar of these is represented by the secretary bird of Africa (family Sagittariidae), a hawklike form that runs on long, stiltlike legs on the ground. The true buzzards

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and hawks with broad wings (family Accipitridae) are as a rule slow-flying species, though the bird-eating species of the genera *Accipiter* and *Astur* are exceptions. They include our familiar marsh, red-tailed, red-shouldered, and rough-legged hawks and the eagles (see Plates 13 and 45). The falcons (family Falconidae) have narrower, more pointed wings and fly expertly, capturing birds in the air with ease.

The gallinaceous birds (order Galliformes) are divided into eight groups, the first being the megapodes or mound birds (family Megapodidae), whose peculiar habits of nesting have already been described (see pages 89-90). The curassows, chachalacas, and guans (family Cracidae), of the New World, are pheasantlike in appearance and live mainly in trees, even nesting high above the ground. The grouse, quail, pheasants, guinea fowls, and turkeys, comprising as many separate families (see Plates 26 and 50), have played a part of tremendous economic value to man. Numerous species of gallinaceous birds other than the domestic fowl, guinea hen, and turkey have been kept in captivity, but none have proved permanently adaptable for life with mankind. The most aberrant living bird of the Galliformes is the hoatzin (*Opisthocomus cristatus*), of South America, which is classed in a separate suborder (Opisthocomi). This bird lives in shrubs and trees bordering streams in Venezuela and Guiana and is so sedentary that it is said to travel only a comparatively short distance from its birthplace during its whole life.

Among the cranelike birds (order Gruiformes) there may be mentioned principally the true cranes, which because of their long necks and wings much resemble herons and storks, though structurally they are quite different. Cranes are confined principally to the continents of the Northern Hemisphere, and in the extreme north are migrant, traveling in bands whose passage is heralded by sonorous trumpet calls that are among the heart-stirring sounds of the out-of-doors. Closely related to the cranes

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are the limpkins, or courlans, of the warmer parts of the New World, which resemble the ibis in form. Limpkins have highly specialized food preferences and live principally on large fresh-water snails of the genus *Ampullaria*, which are found from Florida southward into northern Argentina. In Florida I have watched the limpkin probing in soft mud with its long bill until it encountered a snail, which it pulled to the surface and placed with the shell opening upward. Then with a dexterous flip of the mandibles it removed the horny operculum that closes the shell and with little apparent effort withdrew the snail. The whole performance was done expertly and without injury to the shell.

The rails (family Rallidae), also of this order, include the true rails (Plate 65), the coots, and the gallinules. The true rails inhabit rush-grown swamps, while the coots and the gallinules swim in more open water. The principal peculiarity of the rail family lies in the considerable number of flightless forms its members have developed, all of them on oceanic islands where they have had no enemies that they could not escape by running. Some years ago on Wake Island in the Pacific I had opportunity to study carefully the habits of one of these flightless species (*Hypotaenidia wakensis*). The birds made no attempt whatever to fly. There were no springs or streams on the island and I was puzzled for a time to know where the rails obtained their drinking water. After a day or two, however, I observed that the surface of the island was strewn with shells of a large oyster (of the genus *Tridacna*), cast up by storms from the surrounding reefs. As many of these shells lay with the concavity upward, the daily rains filled them with fresh, sweet water and kept the rails supplied. I took the hint and used this water supply myself to personal advantage.

In the order Gruiformes, also, and closely akin to the rails, come the hemipodes and button quails, the trumpeters, finfeet, kagus, cariamas, and bustards.

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The order Diatrymiformes holds four species of gigantic running birds that are found fossil in the Eocene rocks of western North America. The largest of these, *Diatryma steini*, known from a nearly complete skeleton in the American Museum of Natural History, stood nearly seven feet in height (see Plates 18 and 19). It possessed massive legs, a heavy head as large as that of a horse, a great, arched bill, and very small, almost aborted wings. Though placed here near the cranes and rails, it does not seem to be closely related to either but rather to stand alone.

The great group in which we find the shore birds, gulls, and auks (order Charadriiformes) contains a seemingly incongruous association of families. They are, however, united by definite anatomical peculiarities which warrant their association in one order. The shore-bird group (suborder Charadrii) includes all the sandpipers and plovers (see Plates 11 and 66) and their allies the oyster catchers, phalaropes, crab plovers, thick-knees, pratincoles, seed snipe, and sheathbills. These are principally birds that walk in the water, or wade, comprising large numbers of species which feed about water. Several species, however, frequent uplands, and a few are adapted for life in desert areas. The gulls, terns, and skimmers (suborder Lari) are powerful flyers that search for food on the wing and have webbed feet, so that they rest regularly on the water and swim. The skimmers (family Rynchopidae) are remarkable for two things: The bill is compressed from side to side so that it resembles a blunt-pointed knife, with the lower mandible much longer than the upper; and the pupil of the eye has a vertical slit like the eye of a cat—a form of pupil found in no other bird. The skimmer flies over the water with easy strokes of its long wings, cutting the surface with the lower half of the beak to pick up its food of small fishes. The auks and murre (suborder Alcae), the last of this assemblage, inhabit the sea exclusively—in contrast to the two preceding suborders which

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frequent both salt and fresh water—and secure their food by diving. The beaks of puffins and some others among the auklets have huge, brightly colored sheaths, which are shed at the close of the breeding season. The great auk, a flightless species, is now extinct, the last record of a living bird of this species dating back to 1844. The great auks nested in huge colonies on certain rocky islands and thus offered such an easily obtainable source of food to the early explorers that they slaughtered the birds wholesale. The auk group is confined to the Northern Hemisphere.

The pigeons (order Columbiformes) include a varied group of nearly five hundred species, found throughout the world. The familiar forms of the temperate regions are comparatively plain of plumage, but the fruit pigeons of the Pacific islands display many remarkable colors. The passenger pigeons, of eastern North America, were formerly so abundant that when they migrated their vast hordes actually darkened the sky during their passage. The birds nested in immense colonies, gathering at times in such numbers as to break down the limbs of the trees on which they rested. For many years hunters subjected them to heavy toll, killing literally hundreds of thousands annually for the market. The last great nesting colony known was reported in Michigan in 1881, following which time the birds became steadily rarer, until the last recorded individual died in captivity in the Cincinnati Zoological Park at 1 p.m., central standard time, on September 1, 1914. This bird is now mounted and on exhibition in the National Museum. Though many authorities have stated that the disappearance of this fine bird was due to some catastrophe of nature, it is my firm opinion that uncontrolled slaughter by man exterminated the species, particularly as it was persecuted constantly during the breeding period. The pigeon family has given us one valuable domesticated bird—the common pigeon, which descends from the wild rock dove of western Europe. The

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order Columbiformes includes the dodo, now extinct, and the peculiar birds known as sand grouse, which inhabit barren deserts of the Old World.

The cuckoolike birds (order Cuculiformes) embrace two principal groups—the plantain eaters or turacous (suborder Musophagi), of Africa, and the cuckoos (suborder Cuculi). The cuckoos include a number of curious forms, such as the ground-haunting road runners, of southwestern North America, and the anis, black in plumage, of tropical America. The yellow-billed and black-billed cuckoos, known often as rain crows, are familiar species of our country. Some of the Old World species of this suborder, particularly the European cuckoo, are parasitic in their nesting, depositing their eggs in the nests of other birds, so that the incubation of the eggs and rearing of the young devolve on foster parents. The mother cuckoo ordinarily removes one egg of the bird that she is parasitizing when she leaves one of her own. The young cuckoo when hatched exhibits a most strange and diabolical instinct that inspires it to crowd beneath the eggs or young which really belong in the nest until it gets them on its back, when, by a convulsive movement, it casts them out to destruction. This act seems almost uncanny in a creature just born into the world. For every cuckoo reared thus, a brood of other birds is sacrificed. The foster parents chosen are usually of small size, so that the child foisted upon them grows under their attention to what must seem gigantic proportions.

The parrots (order Psittaciformes) number nearly six hundred species, which, in spite of considerable diversity in size and color, are always recognized without difficulty because of their compact bodies, heavy, rounded heads, and strong, hooked bills. The majority are tropical or subtropical in range, extending clear around the world, with occasional outlying forms in colder regions. The Amazon parrots (genus *Amazona*), of tropical America—species of compact form with short, square tail—the

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African gray parrot (*Psittacus erithacus*), and various kinds of long-tailed parrakeets are familiar as household pets, less in favor now than formerly because of recent studies of a dangerous disease, psittacosis, that they may transmit to man. The kea (*Nestor notabilis*), of New Zealand, another parrot, has fallen into disfavor in its native land because it has developed a habit of attacking living sheep, tearing open their backs to get at the fat across the loins. It acquired this taste from eating fat from the skins of freshly killed sheep about the houses of the settlers. The lorries of Australia and the Polynesian region are distinguished by exceptionally brilliant color (see Plate 41) and by having the tongue developed as a brush. The pygmy parrots of the Papuan islands range from two and four-fifths inches to four inches in length and may be contrasted with the long-tailed macaws of America, which measure nearly three feet. The curious little bat parrots (genus *Loriculus*) of the East Indies and Philippine Islands always sleep hanging upside down. The cockatoos (Plate 69) are interesting species of Australia and near-by islands.

The owls (order Strigiformes) are specialized for seeking food at night. Their large eyes see in very little light, and their wing feathers have softened, fluffy margins, so that they fly without sound. Owls feed principally on small mammals and birds, reptiles, crustaceans, and insects. Many of them have loud, hooting calls, which resound through the night to the terror of the superstitious. The snowy owl forms one exception to nocturnal habit in this group, since it nests in the Arctic tundras and must perforce be abroad by day, in a land where there is no night in summer. At intervals of several years the food supply of small mammals, upon which these birds depend in the north, fails and forces great numbers of them south, far beyond their usual range. Such an invasion occurred in the winter of 1926-27, when hunters killed hundreds of these great white owls in the eastern United States. The burrowing owl, found in the western United States



Lesser yellowlegs (*Totanus flavipes*), a common American shore bird. Photograph by Dr. Frank N. Wilson



Blue jay (*Cyanocitta cristata*), a familiar species of the family of crows and jays. Photograph by Dr. Arthur A. Allen

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and south from there into Patagonia, stands about ten inches in height. It lives in burrows in the ground, sometimes using tunnels made by prairie dogs or other mammals, but, where these are not available, digging its own. It, also, is active by day. The old legend of the West that this owl, the rattlesnake, and the prairie dog lived as a happy family in the same hole is without foundation. The grotesque barn owl enjoys so wide a distribution that, in spite of its strictly nocturnal habits, we may wonder that it is not better known. The disks of feathers about the eyes and the bird's attitude suggest a monkey and have given it its common name—monkey-faced owl.

The next group of birds, the goatsuckers and their allies (order Caprimulgiformes), related to the owls, has many peculiar forms. Many of its members, like the whippoorwill (see Plate 14), chuck-will's-widow, and the nightjars of the Old World are to most persons merely voices that come in the night; for the birds remain hidden by day in dense growths of vegetation, or perch lengthwise on limbs, so nearly resembling the dead leaves or bark on which they rest that they are seldom seen. The night-hawks (see Plate 21) are active to some extent by day, coming out regularly to fly in the evening. The males have an interesting mating display, in which they dart rapidly down toward the earth with set wings and then suddenly turn to produce a loud, roaring sound, caused by the air rushing past their stiffly held wings. The oilbird (*Steatornis*), of northeastern South America, an aberrant member of this order, lives in colonies in caves, sallying forth at night to seek its food of oily seeds. The young become extremely fat and are gathered by the Indians, who try out the grease found in their bodies and use it as a substitute for butter. The fork-tailed goatsucker (*Hydropsalis furcifera*) of South America, though no larger in body than a nighthawk, has a tail fifteen inches long. The ninth primary of the standard-winged goatsucker (*Cosmetornis vexillarius*), of Africa, reaches a length of eighteen inches,

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though the bird itself measures only ten and a half inches.

The swifts and humming birds (order Micropodiformes), though differing decidedly in appearance and habit, are structurally similar, so that they are classified in the same order. Swifts (family Micropodidae), with long, narrow wings and smoothly rounded bodies, resemble swallows, but belong in an entirely different group. They are strictly aerial in their search for insect food; and they perch only by clinging to the face of cliffs, hanging fronds of leaves, the inside of hollow trees and chimneys, or occasionally the inside walls of dark buildings. About one hundred forms of swifts are known, varying in length from three and a half inches to the length of sparrow hawks. The swiftlets, ranging from India to Australia, Fiji, and the Philippines, produce the edible birds' nests prized by the Chinese.

The humming birds (family Trochilidae) include more than five hundred forms, restricted entirely to the New World, finding their greatest center of abundance in the northern Andes. The common hummers of our gardens—often confused by the unobservant with the large hawk moths that come to visit the same flowers—however beautiful they may be, must defer to the superior iridescence of plumage of some of the forms whose range is further south. The males, especially, of many southern species are decorated with spots that in one light appear dull black, but which, at another angle, gleam suddenly blue, green, yellow-green, or deep red. Most humming birds feed at flowers, consuming quantities of nectar but taking also spiders and minute insects (see Plate 52). Some species glean over leaves and the bark of trees in search of small insects and other similar food. Hummers vary greatly in structure, the bill of one form measuring barely a quarter of an inch in length, while that of another is five inches long. Although ordinarily we think of members of the humming-bird family as tiny, the group does have species of large size, such as the giant hummer (*Patagona gigas*) of

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the Andes, whose heavy body measures eight and a half inches in length.

The mouse birds (order Coliiformes), about a foot in length, are characterized by very long tails and short, dense feathers. The head is crested, the bill strong, being almost like that of a finch, and the feet have all four toes directed forward. The twenty-two races at present known are confined to Africa, where they range actively through dense brush. They are said to sleep at night clustered together in great masses, hanging head downward like bats.

The trogons (order Trogoniformes) are found in the tropical and subtropical forests of America and rank among the most colorful birds of the jungle. Most of them are under twelve inches in length, and they are generally metallic green above with areas of deep red or yellow on the under surface. The upper tail coverts of the largest quetzals (*Pharomachrus mocinno*) are developed into graceful streamers nearly three feet in length, deep green in color, and lacy of web. The quetzal is the national bird of Guatemala and is held in the highest esteem in that country. Trogons nest in hollow trees, often in old woodpecker holes, depositing their eggs without bedding material of any kind. The eggs are unmarked, varying from dull white to buff or pale green in different species.

The next group (order Coraciiformes) contains a variety of birds, externally quite different but internally related by various peculiarities of anatomical structure. The order includes such forms as the kingfishers, todies, motmots, bee eaters, hornbills, hoopoes, and others. The belted kingfisher of North America is known as an eater of fish (see Plate 46); but it has various relatives, some plain and some of brilliant plumage, that inhabit dry areas and feed to a considerable extent on lizards and insects (see Plate 54). The tiny todies (family Todidae), somewhat allied to the kingfishers, are less than four inches in length,

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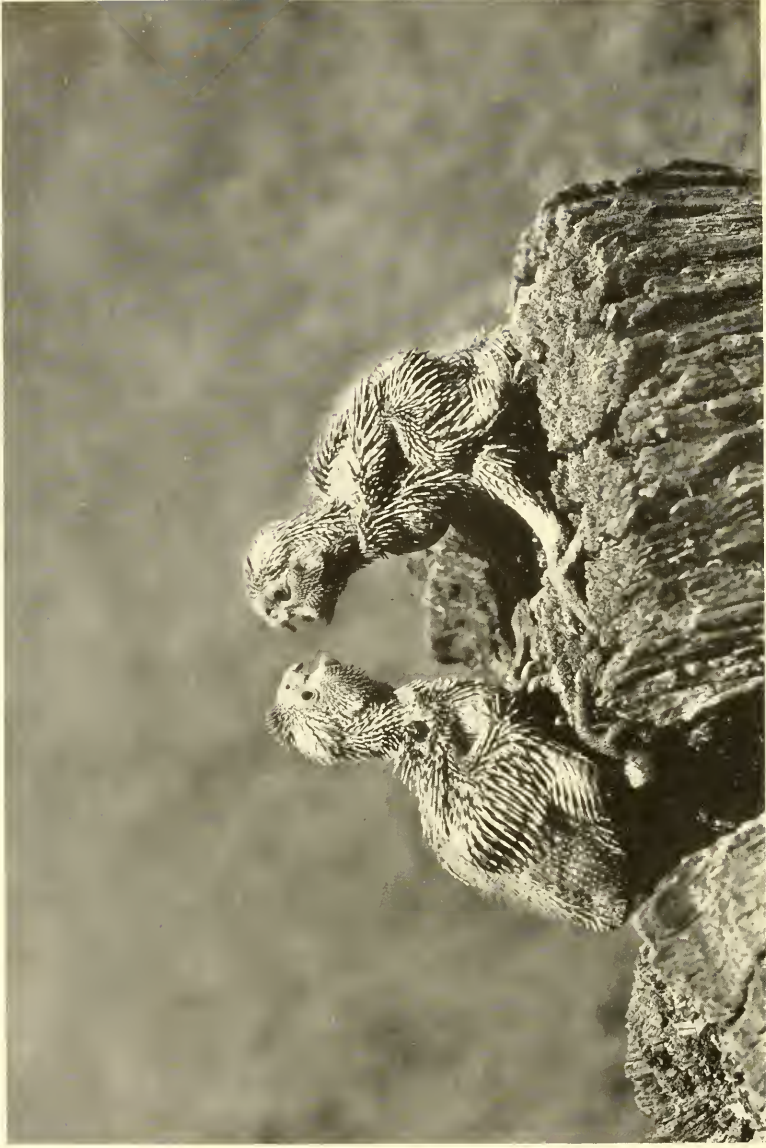
with long bills with which they snap up insects. The five species of todies known are confined to the islands of the Greater Antilles (West Indies). Usually they are deep green above and have brilliant-red throats. They nest in little tunnels which they dig in the face of clay banks. In most of the motmots (family Momotidae), whose habitat is tropical America, the central tail feathers are longer than the others and have racket-shaped tips.

The hornbills (family Bucerotidae), birds of robust body, possess large bills on which are developed a curious casque or growth, which in some species attains such size as to appear almost like a second bill. In spite of its immensity the bill is thin-walled and light in weight except in one species—the solid-casqued hornbill (*Rhinoplax vigil*), in which the whole anterior wall of the casque is thickened and solid, resembling ivory. The ground hornbill of Africa lives on the ground in open country, an exception to other species of the family, which frequent the trees of heavy forests. In the nesting season the female hornbill enters a tree cavity, where her mate walls her in with mud, leaving only a narrow slit through which she may thrust her bill to receive food. In this imprisonment she remains for a period of six or eight weeks, subsisting on food brought by the male, incubating her eggs, and subsequently feeding the young, while at the same time she molts and renews her wing and tail feathers. During this period, the cells in the stomach walls of the male grow rapidly, forming peculiar sacs that when filled with food are regurgitated entire and passed to the female. This whole nesting performance of the hornbills has no known parallel in the bird world.

The puff birds, jacamars, honey guides, woodpeckers, and their allies (order Piciformes) make up a considerable group having as one external character two of their toes projecting forward and two back, an arrangement found also, however, in some other orders, such as the cuckoos and parrots. Woodpeckers (family Picidae) are known to



Bronzed grackle (*Quiscalus quiscula aeneas*), commonly known as the crow blackbird. Photograph by Dr. Frank N. Wilson



Young of the galah, or rose-breasted cockatoo (*Eolophus roseicapillus*) of Australia, removed from their nest.
Photograph by Charles Barrett

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every one with the slightest familiarity with birds. For the most part they are sober-minded workers that climb with sharp claws over the rough bark of tree trunks, bracing themselves with stiffened tail feathers to relieve the strain on their feet. The majority, as would be expected from their habits, are forest birds; but the family seems to be an ancient one for it includes species specialized for life under a variety of conditions. Some are even ground-dwelling; the flickers, for example, are to a considerable extent terrestrial, as is also the peculiar ground woodpecker (*Geocolaptes olivaceus*) of southern Africa. The hairy and downy woodpeckers (genus *Dryobates*) and their allies chisel wood-boring grubs from logs and tree trunks. The red-headed woodpecker and its cousins may seek the same type of food or may feed on berries or on insects caught on the wing. Certain groups have only three toes. The piculets, a subfamily of tiny birds—most of them not much larger than wrens—have soft-pointed tails and run about over limbs like nuthatches.

The honey guides (family Indicatoridae) are African and Asiatic birds that take their common name from a curious habit possessed by some of the African species of leading natives to the nests of bees. Honey guides inhabit forests; and on the approach of men they come fluttering through the branches, calling to attract attention, and then lead the way to a hive of bees. When the honey is rifled, the bird receives its reward in the form of honeycomb containing young bees. Occasionally the habit goes astray, and the bird may lead its follower to a rhinoceros or some other irritable creature!

Nearly half of the birds known to man are included in the perching group (order Passeriformes), sometimes called the sparrowlike birds. This order is distributed throughout the world and includes the majority of our familiar species, such as the robins, jays (Plate 67), wrens, sparrows, warblers, and many others. According to our present understanding, the Passeriformes include sixty-nine fam-

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ilies, one of which (Paleospizidae) is known only in fossil form. These families are distributed among four suborders, the broadbills (Eurylaimi), the flycatcherlike birds (Tyranni), the lyre birds and scrub birds (Menurae), and the true singing birds (Oscines). The species of the order, are, as a whole, small to medium in size; the crows and ravens are among the largest. The singing birds (suborder Oscines), as their group name implies, include the songsters of sweetest voice, though many in the group are not particularly gifted. Though the majority of the Passeriformes inhabit brush, thickets, or forests, living on the ground or among branches, the species are greatly diversified in habit. Among them are the creepers (family Certhiidae) and nuthatches (family Sittidae), which climb on tree trunks; the pipits (genus *Anthus*) and Lapland longspurs (*Calcarius lapponicus*), which inhabit Arctic tundras; the swallows (family Hirundinidae), which spend much of the time on the wing; the shrikes (family Laniidae), some of which are predatory, feeding on other birds, mice and large insects; the dippers (family Cinclidae), which dive into swift-flowing streams to walk about under water; and so on through a list too long to be included in this paper.

This brief review will give some general understanding of the different groups of birds, their diversity of form and habit, and the relation that they bear to one another. The subject of birds is one that is obviously almost without end, if taken in detail, and might in itself be amplified into a long series of entertaining volumes.

PART II
MAMMALS
AND HOW THEY ARE STUDIED

By

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A pair of gibbons from French Indo-China, now living in the National Zoological Park. They illustrate how greatly the sexes in mammals may differ in color and hair pattern. The buff-colored, broad-headed individual is the female

PREFACE

MAMMALS, the animals whose young must be fed on milk, live today in every part of the world except on the most remote islands and on the polar ice caps. All the continents support them, and they flourish in all the seas. The total number of their different kinds has not yet been determined, but it can not be less than twenty thousand.

Buried in caves, deposited in gravels, sands, or clays, and incased in rocks lie the bones of extinct mammals—of kinds that once inhabited the surface of the earth or swam the seas, but now are gone. These creatures of the past, some of them pertaining to the ancestral lines of living mammals and others not directly related to any that we know today, must have exceeded the number of species now in existence by hundreds to one, perhaps by thousands to one.

In the following pages we wish to tell something of the way in which all of these animals are studied and something of what has been learned about them. We shall begin by showing how the fossils are hunted and what kind of stories they tell; how the living sorts are collected; and how this out-of-doors work is supplemented by investigations in our great museums. Then we shall go on to a rapid review of the more interesting kinds of mammals, both living and extinct.

Our object is neither to catalogue facts nor to write a systematic treatise on MAMMALOGY, but to try to give some idea of the interest to be found in a study whose very existence is to most people quite unknown.

While both authors are ready to share the responsibility for all defects in this work, it is to be understood that each has given particular attention to the matter pertaining to his own special field.¹

¹The several restorations of extinct mammals that are scattered through the text are, unless otherwise indicated, the work of M. Elie Cheverlange, done under the direction of Doctor Gidley.

CHAPTER I

PERSONAL EXPERIENCES WITH FOSSIL MAMMALS

A JUNE day in 1903 found me busily at work uncovering and preparing for removal from their ancient bed the bones of a very rare and splendidly preserved skeleton of a small, three-toed horse. The fossil had been discovered in a soft, semiconsolidated sand formation, of prehistoric time, on the Rosebud Indian Reservation in South Dakota. I was alone. My assistant and the camp cook had gone that morning to the Rosebud Agency store for supplies. No human habitation was visible in the great expanse of grass-covered plains and sparsely timbered hills and valleys that surrounded me on all sides, for I was in the midst of the old Sioux country lying to the east of the Black Hills—a bit of the old West not yet disfigured by the hand of the white man. The day was bright and sunny, with occasional soft breezes stirring the tall bunch grass and scattered pines on the hillside and fluttering the leaves in a small grove of cottonwoods close by. No disquieting thought or sense of danger from man or beast disturbed me as I worked, half reclining and all unconscious of everything save the rare and delicate specimen I was uncovering. I knew, of course, that I was far from any white settlement and near the tepees of some of the war chiefs who, not so many years before, had taken an active part in the fight that wiped out General Custer and his troop of cavalry on the Little Big Horn.

In this setting, then, and under this spell of tranquillity, imagine if you can the wild panic that for a brief

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moment seized me, and the unreasoning terror that clutched my heart on hearing a guttural, full-lunged "How!" uttered almost in my ear and nearly above me. My earlier plains training and familiarity with the ways of the Indian prevented me from revealing my fright; and my momentary panic departed as quickly as it had come. Without changing position, then, and scarcely pausing in my work, I looked up to see standing within a few feet of me a tall, powerfully built Sioux. He had evidently sighted me from a distant hilltop and had probably been watching me for some time. Not being able to make out what I was doing he had decided to investigate and had slipped up in true Indian fashion to get as near as possible before making his presence known.

He was just past middle age and his face was that of a seasoned warrior and hunter. A single eagle feather adorned the long straight black hair that hung down over his shoulders in two braids. For clothing he wore the usual dark-red Indian blanket partly covering a faded blue calico shirt and buckskin leggings. On his feet were buckskin moccasins, beautifully ornamented with beads and bright-colored porcupine quills. He carried the bow and arrows for hunting small game, the long-stemmed pipe, and the tobacco pouch typical of the Plains Indian of that day. My first look at this ex-warrior assured me that his intentions were entirely peaceful and that, so far as bodily harm was concerned, I had nothing to fear from him. Anxiety, however, of a very different nature troubled me as I continued to work, with my visitor sitting a few paces distant, peacefully smoking his pipe and watching with keenest interest my every move. I knew he was no Indian if he were not curious and greatly puzzled about what I was doing and if he did not demand an explanation. I soon found he could neither speak nor understand much English; and my fear was that, with my limited knowledge of the Sioux tongue, I would not be able to give a satisfactory account of myself and would

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probably be told I was not welcome there. Fortunately I had much underestimated the intelligence and native reasoning ability of my visitor. What followed left a lasting impression on my memory and increased my respect for the often despised Sioux men of the pioneer days.

The old warrior watched in silence for more than an hour as I continued the delicate process of removing the sand covering, until skull, forefeet, and other parts of the skeleton were revealed, lying articulated and nearly in their natural positions. With a characteristic grunt of satisfaction by which I knew he had come to the end of his own conclusions he arose, and, coming nearer, began talking eagerly, in Sioux, trying to tell me as best he could how he had interpreted the situation. The first words I recognized were "shunktanka cistilla," which is Sioux for "little horse." "Yes," I said, "you are quite right. This is the skeleton of a little horse, but not like the horses living today." Then to my amazement he went on to tell me, by word and expressive gesture, that this was like no animal he had ever seen, but that it was a little horse of adult years; that it was smaller than the Indian pony; and that it had long slender legs, more like those of a deer; and, strangest of all, pointing to the feet, that it had, besides the usual hoofs of the horse, a small extra pair of hoofs on each foot.

Such a display of intelligence was, of course, utterly unexpected. In my turn I tried to make the Indian understand that his conclusions were entirely correct and to explain that this little horse had lived in the very, very long ago, before the coming of his own people, at a time when the whole plains and mountain country of the West and all the animals found there were quite different from the country and animals of our present day. How much of this I succeeded in making clear to him I do not know, but probably very little.

However, we arrived on ground of full understanding when I admired his porcupine-quill moccasins and

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expressed a wish to "swap" for or buy them. He said I might have them for two dollars. Knowing that an Indian always asked more than he expected to receive, and realizing also that it was wise to follow the unwritten law of the time and never to give an Indian the price he first asked, I promptly countered by offering fifty cents. Afterwards I increased my offer to a dollar, which he at once accepted. We shook hands on the bargain and parted the best of friends. My tall Sioux warrior took the coveted silver dollar, placed the moccasins beside me on the ground, and stalked away in his bare feet.

Striking contrasts to the clear, spontaneous reasoning of this Indian are furnished by some of my experiences with people of my own race. A few years after the episode just described I was collecting fossils in the Texas Staked Plains country. Among the good finds that summer was the partial skeleton of a large mammoth, or extinct elephant, known as *Elephas imperator*, the imperial elephant. We had found this at the bottom of a deep ravine, where recent stream action had uncovered small fragments of some of the bones and had thus revealed the presence of the skeleton in the spot where it had lain preserved and securely covered for many thousands of years.

One Saturday rain halted excavations on this specimen and all hands drove in to a small village near by for supplies and mail—two most important things in the life of a fossil hunter. We found the general store crowded with ranchmen and their families, making their week-end purchases. To all of these we at once became the center of attraction; for the news of our having found "big bones" in the canyon had preceded us. Interest in the "big elephant" was general, and, with one exception, friendly. But one man seemed to take our reputed find as a personal insult. He said that no animals larger than the buffalo had ever been in Texas. He averred that bigger animals just naturally could not exist there and

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scientists who said they could were liars and ought not to be allowed to run around the country trying to deceive people.

"Why," he said, "I have lived here for nigh on twenty year, and have rid every canyon and break in this whole dern country, and I haven't never seen nothing like you say you found. There just couldn't 'a' been no sich animals ever lived here."

This seemed to be his final shot, so I ventured the remark that he might be right, but that we had actually found big bones that were just like those of an elephant, only much bigger than the circus variety, and that he was welcome to come and see them for himself. Moreover, I said, bones and teeth of these animals had been found in many places in this southwest country and it seemed to me that the animals to which they belonged must have once lived here, for otherwise I was at a loss to know how the bones came to be where they were dug out. This argument seemed to be a poser, and no reply was forthcoming. Some man in the crowd said: "That seems reasonable, Pete. If you don't believe it, why don't you go down to the canyon tomorrow and see for yourself?" I, of course, backed this with a most cordial invitation, which was accepted.

When the doubter, with his friends, arrived at our camp next day, his skepticism was still quite apparent, but his belligerency had gone. On seeing the bones of the great beast lying in their original bed but sufficiently uncovered to reveal their true character and great size, he lost his skepticism also. A feeling akin to awe seemed to take its place. Before him lay the lower jaws, huge masses of bone, with the two jaw teeth whose grinding surfaces were as wide as a man's hand and nine or ten inches long. Near them a section of a tusk and part of a skull were exposed. He could also see a shoulder blade, more than three feet in length and broad in proportion, as well as the great bones of the foreleg—evidence that could not

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be explained away on any basis of deception or fraud. All were unmistakably the remains of a huge animal, which in life must have stood nearly fourteen feet high and which had carried curved tusks about eight inches thick and more than eleven feet long. There and then our skeptic was forced to yield to the authority of fact.

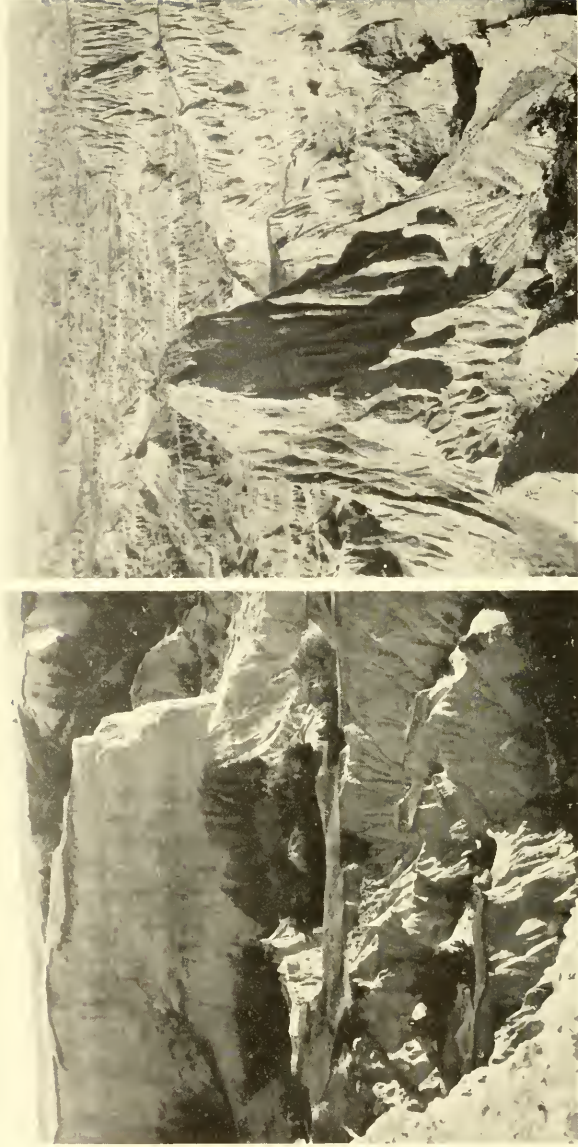
A score of years later, while on a fossil-collecting expedition for the Smithsonian Institution in the San Pedro Valley of southeastern Arizona, I met another but quite different type of skeptic, who also doubted the former existence of animals of elephantine size in America. This was an elderly Mormon, at whose ranch, near the fossil-bone localities of that region, I was fortunate in being able to make my headquarters, and whose son, Milton, served as my field assistant. The old gentleman made up for a lack of formal education by a naturally fine intellect, and I remember with pleasure the evenings of general discussion at his home. After a time I noticed, however, that whenever the talk turned to our finds of fossils, my host grew reticent. When I spoke of this to Milton, he told me that his father was rather skeptical about the former presence in Arizona of animals so different from those the pioneers had found there. Milton and I were just then uncovering a skull and other bones of a rare species of mastodon, an elephantlike creature whose skeleton is now mounted and on exhibition in the National Museum at Washington (Plate 71). We were both curious to know what impression the actual examination of the fossil bones *in situ* would make on his father. Accordingly we persuaded him to accompany us to work the next morning. The broken skull and jaws, with the great spreading tusks each fully six feet in length, were lying in their original bed with the dirt removed sufficiently to show their full outline and general character.

On arriving at the excavation I said: "There is one of



Restoration of a mastodon, *Stegomastodon arizonae*, based on a skeleton in the National Museum. This cousin of the elephant lived in the Southwest during the Pliocene. It stood over seven feet high at the shoulders

PLATE 72



Two views of the Badlands. One looks toward, the other away from the plain out of which the Badlands have been eroded. Courtesy of Dr. Glenn L. Jepsen

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these big animals we have been talking about. Do you think it might be one of your long-horned steers that disappeared and got buried here some years ago?" "No, it couldn't be that," he replied. We went on with our work while the old gentleman watched us for some time in silence, apparently rapt in his own thoughts. In one of our recent evening talks the question of "facts" had been discussed, and we had agreed upon their importance and the great weight that must be given them in discussing theories or preconceived beliefs. His meaning, then, was perfectly clear when, after a while, he arose to his feet, and, pointing at the mastodon skull, exclaimed: "There, now! *That* is a fact. *That's* a fact!" Thus did he frankly admit that his doubts were gone and that he accepted the evidence as complete.

My own experience with fossil hunting began when I visited the Big Badlands, in South Dakota, in the early eighties of the last century. Perhaps an account of this experience will serve to show how fossils are collected and also will explain how they became embedded in the rocks and how we are able to read from them the history of life during long past ages of the earth.

The Badlands ("Mauvaises Terres" of the early French trappers) lie to the east of the southern portion of the Black Hills of South Dakota, and are for the most part included between the Cheyenne and White rivers. They occupy an irregular, basin-shaped area approximately sixty miles long by twenty-five miles wide, which drops below the general level of the surrounding plains by a series of terraces, ridges, and steep inclines to a maximum depth of nearly seven hundred feet. From the level of the surrounding plain one has the impression of viewing a sunken group of miniature rugged and barren mountains (Plate 72). The color of the earth and rocks of which this strange landscape is composed is a very light buff or cream with a greenish cast, shading to reddish tints, especially in the higher levels; and on a clear day the

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sunlight is reflected from peaks, serrate ridges, and steep, irregular slopes in dazzling brightness.

At one time in the long ago this Badlands basin was filled up to the level of the surrounding plain, of which it was an integral part. It was made of horizontally placed layers of slowly accumulated stream deposits, composed for the most part of clays but with a liberal addition at some levels and localities of sand and gravel in varying degrees of coarseness and purity. Time first changed these layers into more or less consolidated rocks of greatly varying thickness and hardness; then, because of changed drainage conditions, the rivers began the gigantic work of scouring, cutting into, and carrying away the accumulated materials. This process, continued through untold centuries, has resulted in the carving out, from a once solid mass of rock, of the marvelously rough and broken country we now call the Big Badlands.

On entering this region from the table-land one descends into a maze of deep, level-floored amphitheatres. Some of the smaller ones are as devoid of vegetation as the irregular walls that surround them. But many have a beautiful carpet of closely matted short grass. In recent years overgrazing of this country has killed out much of the grass, whose place has been taken by the prickly-pear cactus. A few of these basins open broadly into one another, but for the most part they are connected only by a labyrinth of narrow canyons quite bewildering to a visitor not accustomed to their intricate windings.

Traveling through this portion of the Badlands, one sees on all sides the most amazing spectacle of fantastic natural rock carving imaginable. Each turn opens up some new vista of wild beauty and grandeur: here a small cluster of pyramid buttes surrounded by a broken country suggesting the sand hills of the Egyptian desert; there, a series of rounded barren hills stretching away in the distance to be surmounted at the sky line by a long level of broken cliffs like some half-finished and abandoned

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fortification. From one of the many low divides that give opportunity for a general survey of this rough country, the traveler may see countless pinnacles, towers, serrated ridges, and castellated buttes surmounting precipitous escarpments. These form the most conspicuous features of the landscape. In the low angle of a late-afternoon or early-morning sun, the sharply defined shadows give to the whole picture the appearance of some ancient and deserted dream city. By a little aid of the imagination one may readily make out the dim outlines of its broken-down castles and its fortifications tumbling into ruins. The illusion is increased by the presence here and there of patches of creeping juniper and occasional stately cedars, which have taken root on some overhanging crag or in the niches of a cliff.

Toward the west the Badlands become somewhat changed in character. There the larger canyons, as they approach the Cheyenne River, widen rapidly into parks that open broadly on the river valley. Their floors are for the most part covered with grass, but they are more broken and rolling in contour than the open spaces farther eastward and are deeply cut in places by widely meandering stream channels. Cottonwood trees are, or used to be, scattered singly here and there or massed in small groves along these stream channels, which in summer are dry or at best dotted here and there with stagnant pools of water thoroughly impregnated with clay in so fine a state of division that it never settles, but makes the water holes constantly muddy. Towards the end of the dry summer months the water of these pools has about the consistency of thick cream and in color is a dirty light buff. The cattlemen of the region insist that the only way to determine whether a given pool contains water or mud is to thrust a stick in it; if the stick falls over, it's water; if it stands up, it's mud.

As I recall some of my own wanderings in the more remote recesses of this wonderland, the impression of

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deathlike silence and complete solitude is still fresh in my memory. In those days the Big Badlands were yet a part of the Sioux Indian country; but for some reason—probably the scarcity of good water during most of the year—they were not inhabited, and only on rare occasions were they crossed by small parties of Indians or cowboys. Animal and even insect life was almost nonexistent there, so that one had the feeling of being the only living creature in all that desolate region, an anachronism in a left-over bit of the ancient past. In a sense, however, this was not an illusion but a reality; for on all sides were to be found fossil bones, representing the mammalian life of a time so remote that not one of the many kinds then living has persisted until today. These broken and scattered remains lay strewn, sometimes in great profusion, over the Badlands floors at the bases of the little buttes and canyon sides, from which they had been freed by the action of wind, rain, and frost. They were to be found, too, up the slopes and on the ledges of the higher levels, and far down the more deeply cut and broader canyons. Because of their high state of petrification these bones were harder than the rock in which they were embedded. The elements gradually cutting the rock away from them left the fossils to accumulate on the more level places, there to await the first fossil hunters who visited the Badlands.

To the trained fossil hunter, then, the Big Badlands country is much more than just a rough and picturesque terrain. The material of which it is composed, originally deposited in level strata, each layer containing its distinctive assemblage of fossils, is for him a vast depository where for millions of years has been stored and preserved the evidence of the abundant animal life that long ages ago inhabited this general region. The combined quantity of fossil bones taken from this region since its discovery eighty years ago amounts to many thousands of specimens, weighing in the aggregate many tons. Great as this

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amount has been, it is not yet sufficient to reveal all the secrets of the far-past period represented within the limits of the rocks that make up the mass of this collecting field. It has, however, made possible the reconstruction of many of the extinct animals; and these reconstructions, added to our intimate knowledge of the region's geology, enable us to piece together a somewhat detailed history of that long-ago time. This history we are going to trace in Chapter II, partly on account of its own individual interest, but more particularly because it will serve as an example of the results that paleontologists are getting in many localities—in other parts of the United States, in Argentina and Patagonia, in Tibet and India, in Europe, in Egypt, and, more recently, in the Gobi Desert, to mention only a few of the more noteworthy.

Before we attempt to trace the history of the Badlands we wish to give a good example of the field work of the fossil hunter. We shall therefore describe the finding and quarrying of the great titanotheres skeleton that is now on exhibition in the American Museum of Natural History, New York City, where many of our readers may have seen it. The upper half of Plate 74 shows a drawing of the mounted skeleton of a related animal on exhibition in the National Museum, and the lower half of the same plate gives our idea of the animal as it probably appeared when alive. These titanotheres, elephantine in bulk, have no living descendants, but were mammals related to the rhinoceroses. The largest of them must have stood nine feet high at the shoulder; and, with the two hornlike bony outgrowths that curved forward, outward, and upward from their muzzles, they must have presented a truly formidable aspect. In disposition, however, they were probably mild and stupid, for their huge skulls are so well preserved as to show that the brain within them was scarcely larger than a man's fist—about enough to keep the enormous body in working order without generating much surplus mental force to be expended in belligerency.

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Late one summer a party of fossil hunters established camp at the head of a Badlands canyon locally known as Little Corral Draw. Grass for the horses was abundant there; and through expert prospecting in the moist sand of the otherwise dry creek bed and by a little digging we had located a small but adequate supply of cool, fresh water. This trick of finding good drinking water in the heart of the Badlands, labeled by both Indian and cowboy "without water during the dry season," belongs to the credit of the early fossil hunter, driven as he was, by the unfavorable situation of many of the most important collecting fields, to camp in a barren country where all supplies had to be brought by means of horses. Since the days of the automobile, however, supplies of all kinds can be transported almost anywhere, and the fossil hunter is no longer vexed with the water and grass problem. There were four of us in the party: Dr. Jacob L. Wortman, then in charge of the field work of the American Museum of Natural History; Mr. August Peterson, now of the Carnegie Museum in Pittsburgh; the camp cook; and the writer, James W. Gidley. As we rode leisurely campward across a beautiful basin park one evening, after a hard day's toil under the broiling desert sun, the doctor, according to his custom on such occasions, was discoursing on the fine points of our occupation. This evening he seemed especially intent on impressing us with the importance of employing systematic methods in searching for fossils as well as in collecting them. He had been telling us how important it was, in following along certain fossil-bearing levels in search of specimens, to examine systematically every exposure, regardless of how unpromising it might appear from a distance.

As we rode out from behind a headland, the keen eye of the doctor noted a small, inconspicuous sandstone-capped butte, rising scarcely more than ten feet above the level of the basin floor and perhaps a quarter of a mile off our direct course to camp. Pointing it out he

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asked if either of us had examined that little "exposure." We had not, so at his suggestion we all rode over to look at it. When we arrived, the prospect of finding fossils there appeared but little brighter than it had seemed from a distance. However, a few inconspicuous fragments of bone were scattered over the Badlands floor at the base of the butte; and search soon disclosed small pieces still *in situ*. One of these proved to be the broken end of a large rib. Following up this "lead" we uncovered two more rib ends; and, as an even more important sign, we found that the three ribs led into the soft rock parallel to each other. This suggested that somewhere inside the rock might lie the backbone to which the ribs seemed to be still attached, and that perhaps other parts of the skeleton also might be there. While the doctor and I were examining the ribs, Peterson had uncovered a few feet away some toe bones lying in natural, undisturbed position—the most promising indication of all.

This was sufficient evidence to enable the experienced doctor to size up the situation very accurately. With only these rib ends and the bones of a forefoot in view, he announced his opinion that we had at last found the long-sought skeleton of the great *Titanotherium*. Examining these few bones he seemed to be able to visualize almost the exact position in which the rest of the skeleton must be lying, back there under the mass of the hill. He took no pains to conceal his joy, not so much that the wisdom of his theories of how to find fossils had been so quickly and completely vindicated, as that here was in immediate prospect the obtaining of a prize much coveted in the world of paleontology. The correctness of Doctor Wortman's surmise was soon to be verified.

The next morning the work of excavation was enthusiastically begun. And it was then that I received my first expert instruction in the proper methods of collecting and preparing for shipment the fossil bones of a big animal. Here was the greater part of the skeleton of an animal as

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large as a circus elephant, lying buried in rock of uneven hardness and texture but for the most part about like hard-baked sandy clay. The bones had been flattened down and slightly pulled apart before burial. Afterward they had been somewhat crushed and broken by the great weight of the hundreds of feet of rock sediment that had been gradually piled upon them. To add to the difficulties of recovery, the matrix, or rock surrounding the bones, had been checked and cracked at irregular angles by the alternating action of heat and cold, rain and drought; and the cracks, where they passed through or came in contact with the fossil bones, had checked and shattered these as well, making them in some instances most delicate to handle. Under such conditions it may be readily understood that the collecting of the gigantic skeleton was no job for a novice.

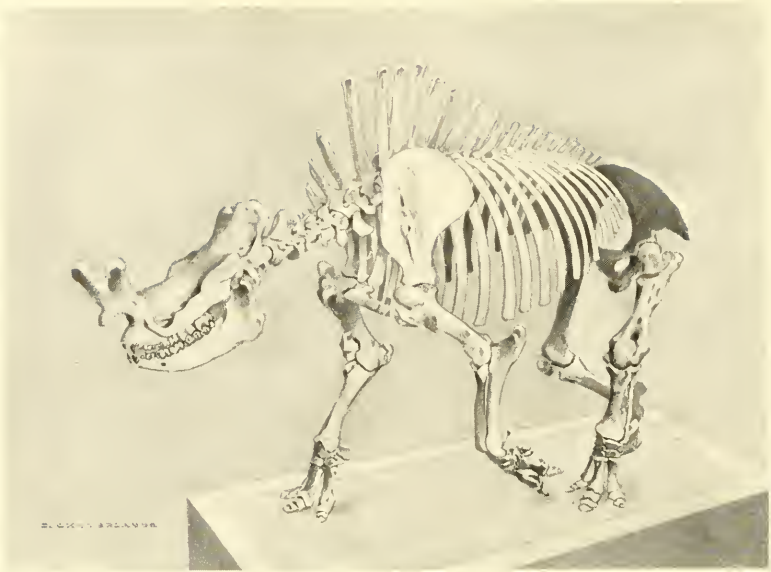
Before the actual excavating began we gathered from the surface all pieces of bone that might by any chance be weathered-out fragments of the titanotherium. These were wrapped in small bundles and labeled "surface fragments." The label also bore the date, field number assigned to the skeleton, locality, and exact horizon, or level, in which the skeleton was buried. The first step in uncovering the buried skeleton was to strip the overburden rock down to within a few inches of the bones. We began with heavy pick and shovel, but as the bones were more closely approached we cautiously continued with small, long-pointed picks made for the purpose. Finally, delicate chisels and brushes were used to remove the rock from the top and sides of each bone as it was freed from its envelope.

Of course a specimen of such unusual size and weight had to be taken up in sections, either as separate bones or in blocks containing a compact group of bones, such as a foot or a part of the spinal column, each section being planned to conform so far as possible to the natural cracks in the rock surrounding the bone. To accomplish

PLATE 73



A typical Badlands landscape, showing the layer-cake form in which its constituent strata were laid down.
Courtesy of Dr. Glenn L. Jepsen



Skeleton of a titanothere, *Brontotherium hatcheri*, in the National Museum, and restoration based thereon. By supplying the muscles needed to move the huge frame and then covering the creature with rhinoceroslike skin, we get an idea of the titanothere's probable appearance in life

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this—to keep the bones in each block intact and get rid of superfluous rock—required the skill of a stonemason, the judgment of an engineer, and the deft fingers of a jeweler.

In preparing each block for removal as we uncovered it we first carefully trenched around it and undermined it with the small picks and chisels. Next we saturated all cracks and other weakened portions of the exposed bone surfaces with a thin solution of gum arabic, which acted as a solidifying medium to prevent crumbling, and covered these surfaces, especially all broken corners of bones, with two or three layers of tissue paper held in place by moistening them with gum water. Then we incased the whole mass in broad strips of burlap dipped in a thick raw-flour paste. (Strips thus treated form when dry a tough, rigid case that firmly holds loose pieces in place and reduces to a minimum all danger of damage in moving.) Finally, we cut the blocks loose from beneath, turned them over, and treated them in like manner on the underside, thus completing the shipping jacket.

As our excavating proceeded, the work became more interesting, and, incidentally, more intricate. Both forefeet had been found and removed, together with their articulating lower-leg bones, before the eagerly looked-for skull, more than three feet in length, was discovered well back under the hard sandstone cap of the little butte. Here another problem presented itself for solution before we could proceed much further with the collecting of our skeleton. For this cap rock—more than two feet thick and too hard to be cut down with the big picks—together with about six feet of rock somewhat softer, yet also very resistant, had to be removed before we could reach the layer in which the skull, backbone, and other parts of the skeleton lay buried. Dynamite was suggested; but knowing the tremendous downward action of this high-speed explosive, we decided to use the slower but more effective lifting agent—blasting powder. Accordingly we

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procured drills, powder, and fuse from the nearest miners' supply store, and so in time brought our excavating to a successful end.

One more important operation, that of packing, remained to be performed before the prize of our season's labor was ready for its long journey to New York. Lumber for making boxes is always considered a part of the regular equipment of a fossil-hunter's camp, and from our supply we proceeded to make boxes for packing the skeleton. Former experience had shown that heavy, irregularly shaped specimens such as those we were handling must be solidly packed in order to escape damage in transportation. To accomplish this we made the packing box for each piece of such a size that when the specimen was lifted in it would neither touch the sides of the box nor leave a space of more than an inch.

Excelsior makes an ideal packing material, but it was not then to be had. However, we found a good substitute in the short buffalo grass and coarse bunch grass that grew in the immediate vicinity. In place of a mowing machine we used axes, butcher knives, or any edged tool the camp afforded for harvesting our crop. A few hours diligent work by all hands, including the cook, procured the necessary material, and the packing was soon under way.

To find a skeleton as complete as the one whose discovery and excavating has just been described is, in most fossil-bearing deposits, a rare and noteworthy experience. Even to come upon a perfect skull is an event for the paleontologist to remember. Most of the specimens found in the course of routine work are merely broken and scattered parts. Consequently, the first necessity for an intelligent study of ancient life is a great abundance of material. It is said that Prof. O. C. Marsh, a bold, energetic pioneer collector, was accustomed to tell his field men: "Remember rule No. 1; save all the pieces." Frequently it is no easy task to save all the pieces, and

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sometimes it requires great skill to do justice to some rare but not well-preserved specimen. The great importance of special training in collecting and handling fossil bones was soon recognized; but most of the earlier expeditions, although under the personal direction of the best men of the time, were hampered by lack of this essential knowledge.

In the days when exploration of the Badlands country began, many specimens, including skulls and other important parts of skeletons, as we have already explained, could be found strewn about in relative abundance on the floors and gentler slopes of the canyon sides. But these surface specimens, through the action of weathering, are usually more or less broken, so that many of their important parts may be destroyed or scattered and lost. Therefore, the best preserved and most complete fossils must be sought and quarried where they lie in the undisturbed body of the beds. As all trained collectors now recognize this fact, they have come to regard surface fragments chiefly as indicators or "leads" to guide them in their search.

CHAPTER II

HOW HISTORY IS READ FROM THE FOSSIL RECORD

It must now be plain that fossil hunting is a highly technical calling which gives men plenty of outdoor exercise and brings them into contact with varied aspects of nature and humanity. But, stimulating and valuable though all this may be, it is not the final goal. The real object of the work is to find bits of the ancient life record that can be pieced together into an orderly history of the past. To give some idea of the results to which all this study leads we shall now relate the history of the South Dakota Badlands.

The entire Badlands area, as we find it today, is an enormous irregularly depressed terrain, characterized by barren slopes and rugged cliffs and canyons, which has been cut by slow, natural erosion into a mass of rocks differing slightly from each other in consistency and arranged like the layers of a variegated layer cake. Whence came the materials from which these layers were made? How were they spread out and built up? How can one layer be distinguished from another? What kinds of life existed while each layer was being formed? These are some of the questions that we shall undertake to answer.

Cross sections of the Badlands mass, exposed by the numerous deeply cut canyons, show not only that it is made up of numerous nearly horizontally deposited layers but that this six hundred feet or more of sediment is divided into three or four distinct zones, differing slightly

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from each other in the material of which they are composed and in the kinds of fossil bones that they contain. Each zone, from bottom to top, may be read like the chapters of a book in which nature has written her own record in chronologic order.

These records tell us that in the dawn of the ancient time period that ushered in the building up of the Badlands formation the entire region was as different in general aspect from what it is now as can well be imagined. There was no single drainage system like that of the Cheyenne and its branches, which now serves it, nor were there any deeply cut canyons in the broad plains country that surrounded the Black Hills on all sides. This ancient plain was the remnant of a sea bottom vastly older than the plain. Long before the granitic mass forming the Black Hills was thrust upward by the action of great internal earth forces, a salt sea extended in a broad belt from the Gulf of Mexico to the Arctic Ocean and covered this entire region, as well as the country extending west of it to and even beyond the present site of the Rocky Mountains.

Today some of the peaks of the Black Hills stand above the surrounding plain to a height of about 5,000 feet, and the main mass has an average local elevation of about 3,000 feet. But at the time when our history begins this pre-Black Hills mountain range was much higher, possibly rising in places to the realm of perpetual snow. From the base of this grand mountain group the section of country in which we are here more especially interested and which we may call the pre-Badlands plain spread out to the eastward, an unbroken, slightly undulating, and nearly level country. It reached well beyond the region where now flows the turbulent Missouri River. In all its expanse there were no Cheyenne and White rivers and no Missouri. But if we could have looked eastward from some mountain height, the panorama presented to us in the glare of a rising sun would have revealed sinuous threads of

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reflected, silvery light, marking the meanderings of perhaps a dozen streams leading away from the mountains in their placid courses over this pre-Badlands plain toward the great central valley to the east.

These streams had their origin high up and far back on the steep, eastern slope of the early Black Hills watershed, whence they were constantly bringing great quantities of broken-down rock in the form of mud, sand, gravel, and larger stones. As they emerged upon the plain their currents lost the force needed to carry the load gathered on the mountain side, and a rapid dumping of their sediment burden resulted, filling up the stream beds and causing frequent shifting and changing of the stream courses. The muds were deposited in the more quiet waters; the sands and gravels were mostly laid down where water currents were moderately rapid. This general process of rock building must have continued for a very long period—doubtless to be reckoned by millions of years—with only slight interruptions and variations. It did not cease until more than six hundred feet of sediment had been laid down.

Upon the slowly accumulating river sediment, as it began to spread over the abandoned floor of the ancient sea, vegetation promptly gained a footing and soon transformed the region into an inviting habitat for many kinds of animals. This is shown by the abundant fossil plants found in the finer deposits at all levels, including the lowest. With the establishment of suitable vegetation began the invasion of the plains by the forerunners of the assemblage of mammals that was destined, with its descendants, to live there throughout the ages needed for the building up of the sedimentary rocks in whose layers the skeletons were buried and preserved, to reappear in our day under the slow action of natural erosive forces and the energetic operations of fossil hunters.

In its dawn period, when the first mammalian invaders must have entered it, the slowly upbuilding region probably

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presented a varied assortment of local features. Vegetation doubtless was abundant along the stream courses and near the foothills, though over the open plain there would have been many barren areas of flood material. Bordering the streams, undoubtedly, were heavy fringes of shrubs, tall grasses, and bushes, with occasional trees in small groves and scattered singly along the irregular meanderings. Here and there, also, were to be found lakes and ponds occupying low places and the abandoned oxbow bends of the ever-shifting stream channels. These ponds must have been frequently replenished from the muddy overflow of the streams in flood time. Thus they would gradually be filled with mud and fine sand before the streams shifted their courses to other areas during the building upward of the general surface level. There is evidence too that wind action had much to do with the shifting and spreading of this building-up material.

The first mammals to appear on the ancient Dakota plain seem, from a modern viewpoint, a truly strange assemblage; especially strange for the American continent because in many ways it suggests the present fauna of Africa. Most conspicuous among the early arrivals were the great titanotheres, or "Titan-beasts" (Plate 74), descendants of others which, at a yet earlier period, had inhabited the region that is now Utah and Wyoming. These creatures were of elephantine size, but of proportions and a general appearance more resembling the "square-mouthed" or "white" African rhinoceros of the present day. In detail, however, they were unlike our "rhinos." Their most noticeable characteristic was the possession of two long, bony outgrowths on the head, something like the horn cores of cattle, but differently shaped and differently placed. For, strangely enough, these outgrowths stood, one on each side, at the extremity of the short muzzle in front of the eyes instead of at the back of the skull. They probably bore horns, but of just what nature is not known. The living rhinoceroses, distant relatives

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but not descendants of these beasts, have horns on the nose—sometimes one, sometimes two—developed from the skin, but these are always placed on the middle line of the face and they have no supporting pillars of bone.

It is difficult to picture the titanotheres as other than awkward, slow-moving creatures, thick-skinned, dull of comprehension like their living relatives, and paying little attention to what was going on around them, their chief concern being the daily quest for food and water. Their great bulk in itself was ample guarantee against harm from possible enemies. But they may have been occasionally ill-tempered, for we sometimes find a fossil rib that had been broken and healed during life—circumstantial evidence that fights were not infrequent. Probably the complacent sun of that time witnessed many unwieldy battles for supremacy between enormous bulls of rival herds.

Here, also, might have been seen, in fewer numbers, animals of much smaller size, true rhinoceroses—near relatives, if not actual forerunners, of those now living exclusively in the Old World. Though too small to be serious rivals of the titanotheres, at least in individual combat, they were not much inferior in size to the smaller African rhinos of today. Out on the plain there had also appeared, in limited numbers, even smaller relatives of the true rhinos. These animals, known as *Hyracodon* (a name given in allusion to their peculiar teeth), were of a form very unusual for their tribe. Long-limbed and slender-footed, they were probably swift runners, agile and graceful in their motions (Plate 76).

Still other creatures, known as entelodonts, which were not at all related to the rhinos though almost as large as some of them, were probably frequent visitors to the shallow, muddy ponds and low, wet swales, where they wallowed and grubbed for favorite tubers or foraged under the trees for fruits or nuts in season. They were hoglike mammals, with long, slender muzzles, and with the



Restoration of *Entelodon mortoni*, a mammal related to the pig but larger and probably more agile than any modern pig. It flourished during the building up of the pre-Badlands plain



Restoration of a saber-toothed cat, *Hoplophoneus robustus*, attacking a lightly built rhinoceros, *Hyacodon nebrascensis*. The cat was the size of a small puma. The animals lived during the building up of the pre-Badlands plain

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cheeks and jaws curiously ornamented with bony prominences, the utility of which, if any, can only be conjectured (Plate 75). They were relatively long-limbed and at need or desire were probably able to get away at a lively gait.

In matter of size the four kinds of animals just described constituted the big game of their day. But it must not be supposed that all the mammals of that time were large; for, sharing with their great neighbors the rich grasslands of the plains, were many small creatures, among them active troops of three-toed horses no bigger than collie dogs (Plate 77). These tiny horses, technically known as *Mesohippus*, or "middle-horses," were the ancestors of the many closely similar kinds—a few genera and many species—that long continued to occupy the pre-Badlands plain region, as well as of other more modified genera, some of which lasted almost to the dawn of human history. Their long, slender legs and bodies mark the "middle-horses" as probably the most efficient running creatures of their time, even as are their descendants of today. But, as with the great titanotheres, these little horses of the pre-Badlands plain are not the oldest horses known, for numerous fossil remains of their ancestors have been found elsewhere in older rocks.

Flesh eaters, as might be expected, came with the rest of the mammals to the Badlands plain; but conditions seem to have been unfavorable for preserving their remains and we consequently know little about them. There were also other animals of less interest from our present point of view. In the rivers lived a few soft-shelled turtles and an occasional crocodile, and on the plains were appearing peculiar types of lizards and a kind of land tortoise. Tortoises became especially numerous; and continued so during the later part of this period. Doubtless birds of many kinds were present on the plain throughout the period of its upbuilding, but conditions seem to have been unfavorable to the preservation of their thin-walled,

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hollow bones. Positive evidence of the presence of at least one species of bird during the period of the titanotheres is furnished by a few fossil eggshells. Judged by these eggs, this bird must have been about the size of a duck.

Years rolled on, centuries waxed and waned, generation after generation of the prehistoric mammals lived and died. Yet little appreciable change either in the animal life or the physical character of the pre-Badlands plain country took place. During these centuries the sediments—sand, gravel, and clay—brought down from the mountains by the frequently shifting streams, accumulated finally to more than fifty feet in thickness. This piling up of deposits went on so slowly that the growth and increase of both plant and animal life were not sensibly affected by it; and, save for possible increase of the timber-covered areas and the more complete occupancy of the formerly barren portions by shrubs, grasses, and other vegetation, the general physical aspect of the country must have remained practically without change.

When the plains had been built up to about the fifty-foot level, and for no reason yet discovered, there appeared on the scene a second invasion of animal life. The chief importance of this invasion was that it noticeably increased the number of kinds of titanotheres. With the addition of the new invaders there were now no less than four distinct genera of these "Titan-beasts" living in this region, each genus represented by several species.

Other centuries rolled around, until the continued slow accumulation of river sediments had added another hundred feet or more to the total deposit on the plain. Then, for reasons that can not even be conjectured, the mighty titanotheres abruptly vanished from the regions where they had formerly roamed as undisputed monarchs. This disappearance is the more inexplicable because most of the animals that had been the great beasts' companions remained on through the next long era. Nor may the titanotheres' exit from the scene be attributed to emigra-

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tion; for in no rocks of later geologic age have we anywhere found fossil remains of them or of animals that might be their descendants. The story of the gradual rise and sudden eclipse of the titanotheres is an interesting one; and although we know nothing of the earliest development of the group, the fossil record left by these giants is remarkably complete for the period that it covers, dating as it does from an era considerably earlier than their arrival on the scene of our present story and continuing up to the time when they totally disappeared.

While we are ignorant of the causes that led to the extinction of the titanotheres,¹ we find evidence in the character of the Badlands rocks that changes in the physical conditions of the region were taking place at about the same time. Possibly a slight general upward earth movement or some alteration in climate may have occurred. In any case, it is certain that there was a change in the character of the rock layers then being built up by the mountain-born streams. No longer did these streams meander freely, as hitherto they had done. Apparently their many indefinite courses out over the plain became united into fewer, less freely shifting, and somewhat deeper channels. This is indicated by the fact that the sand and gravel deposits in the rock layers immediately above those containing the last titanotheres are confined to more limited lanes than the corresponding deposits of the underlying layers, while the purer clay deposits laid down by the seasonal flood and freshet overflows of mud-laden water are more widely spread than ever on the broad expanse of plain bordering the main river course. Wind action during dry seasons also contributed to the general accumulating of sediment, or at least to its rearrangement.

Whatever may have caused this change in the character

¹ Readers who may be particularly interested in the subject of extinction should consult the wealth of information brought together by Prof. Henry F. Osborn in U. S. Geological Survey Monograph 55, Vol. II, 1929, under the following heading: Natural selection in mammals; causes of the extinction of the titanotheres and other quadrupeds.

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of the rock layers, and whatever the new climatic and other conditions that may have arisen, something evidently had a profound influence on animal life. Not long, geologically speaking, after the disappearance of the titanotheres there began an animal migration that brought to the pre-Badlands plain several new and strange creatures to mingle with the slightly modified kinds left over from the earlier time just described. As direct descendants of the first invaders we recognize the flesh eaters, the little three-toed horses, the large piglike animals with the queer cheeks and jaws, the small rhinoceroses, the running rhinoceroses, or hyracodons, and a few others of less importance, all of which had begun to make their appearance in the time of the titanotheres. Their new associates include many kinds showing great variety in form and size. A picture of that time would reveal first and most conspicuously the presence of the newcomers. Then, as we looked at it more closely, we should discern the less obvious though very important fact that changes had come about in all the creatures surviving from the days of the titanotheres. For example, the ruminants, or cud chewers, formerly rare, had now become very numerous, being represented by no less than four very distinct major kinds. Two of them, at least, probably lived in flocks. These two, while differing widely from each other, belonged to a great extinct group known as the oreodonts. Bands of these oreodonts may well have resembled flocks of small sheep when observed at a distance on the plain; but on nearer view the individual animals would have been seen to be larger-bodied, shorter-legged, and longer-tailed than sheep; actually they were not at all like them.

Some of the oreodonts' characteristics, especially the structure of their cheek teeth, suggest a relationship to the deer, while their possession of four large tusks is a piglike feature. But in reality they were not closely related to either the deer or the pig. Although the structure of their jaws and cheek teeth was perfectly adapted to



Restoration of the little three-toed horse, *Mesohippus bairdi*, which lived during the building up of the pre-Badlands plain. When full-grown it was only about eighteen inches high at the shoulders



Restoration of *Agriochœrus*, an orcodont which lived during the building up of the pre-Badlands plain. It was about the size of a sheep, except that its body was longer; and, though a vegetable eater, it had a long, heavy tail and compressed clawlike hoofs

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cud chewing, the oreodonts differed from all other known ruminants in having in the upper as well as the lower jaw a well-developed row of nippers, or grazing teeth—a character typical of such widely different animals as the pigs and horses, animals which, as everyone knows, have hoofs but chew no cud. Also, the oreodonts had five toes on each foot—four of which were of almost equal size, while the fifth was on the verge of disappearance—instead of the usual one or two possessed by present-day hoofed animals. Like many of their contemporaries, they have no living descendants and no closely allied living relatives; hence they lack a common name. Paleontologists call the smaller and more abundant of the two genera here considered *Merycoïdodon*, a name signifying the possession of teeth like a ruminant.

The other and larger kind of oreodont (Plate 78) is known as *Agriochœrus* (meaning “wild-hog”). It was long-bodied, short-legged, and long-tailed, and like *Merycoïdodon* it was essentially four-toed. But its toes were very peculiar, and the differences noted in the structure of the toes furnish the chief distinguishing mark between the two kinds of oreodonts. The toes of the merycoïdodons terminated in little, well-rounded hoofs, but in the agriochœres the hoofs were very much compressed, resembling more the narrow high claws of a bear or cat than a true hoof. Because of this feature, it has been suggested that these animals, although they were cud chewers and were possessed of teeth adapted to ground feeding, may have sometimes climbed trees.

This very unusual type of hoof, wholly unexpected among ruminants, led to a rather amusing though entirely excusable case of mistaken identity at a time when the agriochœres were known only from fragmentary and unassociated parts of skulls and skeletons. The first fossil remains of these animals were discovered in 1850 when a portion of a skull with its teeth came into the hands of Dr. Joseph Leidy and was described by him as

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part of a ruminant, or cud chewer. Many years later, while with one of the American Museum expeditions, I had the good fortune to discover and collect in the Big Badlands a complete hind foot, with all bones in place, of an entirely unknown type. The ankle bones were like those of a ruminant, but the end toe bones were thin and sharp like the claws of a flesh eater. Osborn and Wortman then described this foot as representing a hitherto unknown kind of animal; and because of the peculiar combination of characteristics, they gave it the name *Artionyx*, which means "clawed-even-toed" animal. Soon after their description appeared, Prof. W. B. Scott, of Princeton University, called attention to the fact that the foot structure of *Agriochœrus* was not then known, and also that the teeth of *Artionyx* were unknown, yet both animals were evidently ungulates and of equivalent size. Hence he reasoned that when more complete specimens were discovered the two supposedly different creatures would prove to be one. Professor Scott did not have to wait long to see his keen anatomical judgment vindicated. For the very next summer two fossil specimens were found, one by Mr. J. B. Hatcher, the other by me, in which the teeth and feet of a single individual were undeniably associated. Both fully confirmed Professor Scott's prediction.

Another type of ruminant (known as *Leptomeryx*), much more nearly related to the true deer than any others of its order then living, was no bigger than a rabbit. These little creatures have left their fossil remains so abundantly as to suggest that they must have lived in troops among the undergrowth or dense grass of the plain, behaving, probably, like the equally small dik-diks now found in Africa, or the "mouse-deer" of the Malay region.

Still another kind of animal belonging to the cud chewers that came to the ancient plains country at this time was a sort of primitive camel about the size of a very small deer, but more like the South American llama in

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general build. These little camels, long of limb and neck, were evidently agile but perhaps somewhat awkward in gait. They were possible ancestors of the present-day camels. Even at this early time they had developed some of those characteristics that make our camels such tireless travelers; and in imagination we may see them roaming the ancient plain in search of food much farther away from the water courses than the other grazers of their day might care to venture, except, perhaps, their grazing rivals, the little three-toed horses. Plate 79 shows a skeleton of a near relative of these small camels in the position in which it was found in rocks of a somewhat later date and slightly south of the limits of the Badlands.

At this time the pre-Badlands plain was inhabited by no less than three distinct kinds of rhinoceroses. Two of them were slightly modified descendants of our old friends, the companions of the titanotheres, namely, the large, unwieldy "true" rhinoceroses and the small, agile hyracodonts. Those of the third kind were newcomers to the region. In size they about equaled the familiar African black rhino, but in build they were very peculiar—heavy-bodied and excessively short-limbed (Plate 80). Because of their general form and also because of certain peculiarities in their tooth structure, but more especially because their fossil remains have been found nowhere else than in the river-channel deposits of the Badlands, these short-legged rhinos are supposed to have been aquatic in habit, frequenting rivers much as African hippopotamuses do today.

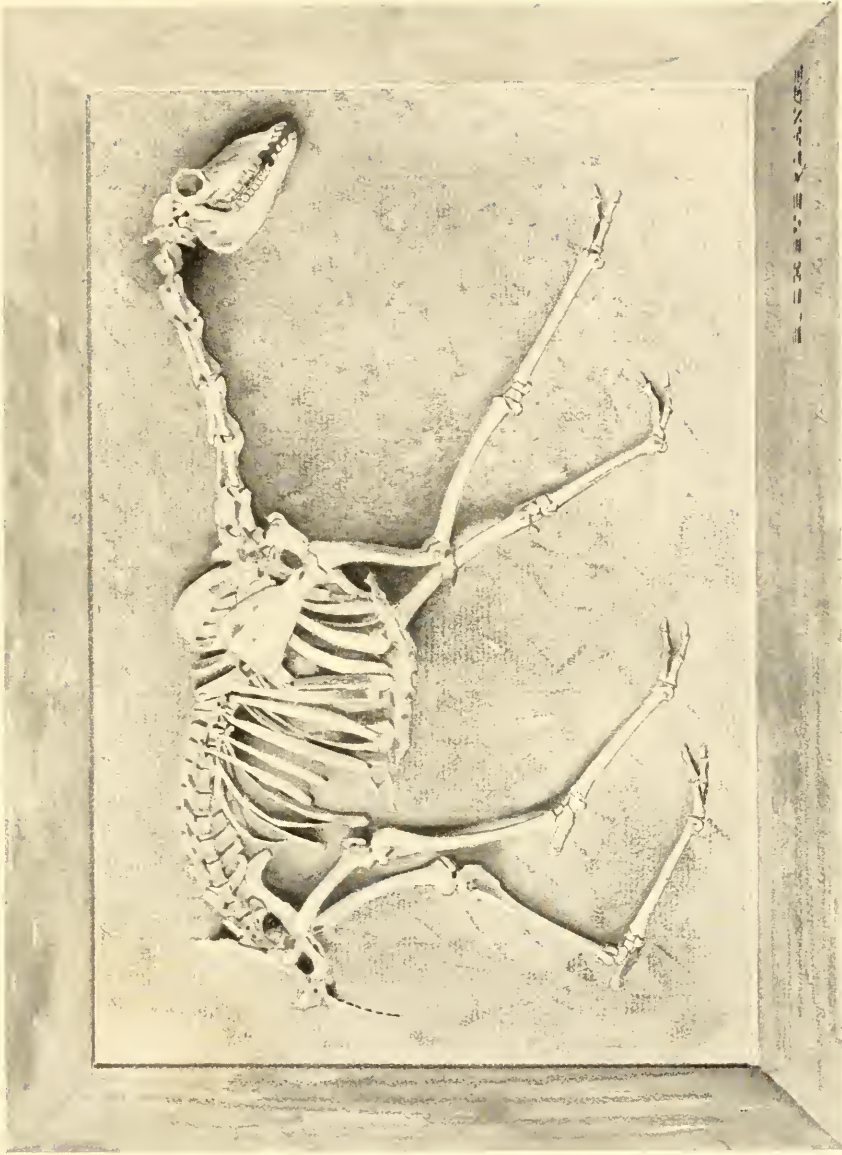
There were also primitive tapirs of small size; and many others of the smaller kinds of mammals might now be seen, each in its appropriate environment. Among the trees and on the open ground spaces there were squirrels of different kinds; and in the copses there were small opossumlike creatures; while along the river banks lived small rodents, relatives of the beavers. Two small insect-eating

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mammals, one like the moles, the other like the Old World hedgehogs, found among the undergrowth a congenial home.

The scene as thus far outlined may appear to be too peaceful. But killers were there and were becoming increasingly abundant; or at least conditions for their preservation were more favorable than they had been in the days of the titanotheres. Consequently at this higher level we find their fossil remains plentiful in number and varied in kind. Among these flesh eaters, two genera of large, long-headed cats, or saber-teeth—so called because their upper jaws were furnished with a pair of prominent saber-shaped tusks, or canine teeth—must have been a constant menace to the little three-toed horses, the camels, and the diminutive deer. On occasion they may even have marked the small rhinoceroses as their prey (Plate 76). Primitive wolves, one kind the size of our coyote, the other not more than half as large, also helped to make life miserable for the little plant eaters. A third kind of flesh eater, the *Hyaenodon*, or “hyena-tooth,” represented by two species, the larger of which was the size of a large wolf (Plate 81), may sometimes have taken part in the kill; but, as its name implies, this creature is thought to have had rather the carrion-feeding habits of the hyenas. Probably, therefore, *Hyaenodon* was a night prowler, subsisting for the most part on the remnants of feasts left by the real killers.

Such was the general aspect of animal life on the pre-Badlands plain at the beginning of the period that followed the disappearance of the titanotheres. And such it remained with only slight changes, occurring long ages apart, throughout a span of centuries even greater than that which had seen the rise and fall of the great “Titan-beasts” in the Dakota country. The short-legged river rhinos went to an early extinction, but descendants of most of the other lines of mammals lived on. Through all these later centuries, however, sedimentary accumula-



Complete skeleton of a small camel, *Stenonyx gracilis*, lying as it was found, incased in the topmost layer of the rocks that formed the pre-Badlands plain. In life this camel stood about two and a half feet high at the shoulders. Specimen in the National Museum



U. S. NATIONAL MUSEUM

Skeleton of the short-legged New World rhinoceros, *Teleoceras fossiger*, which, like the modern hippopotamus, probably lived in the water. It was abundant in the Great Plains region after the pre-Badlands plain had been built up. Specimen in the National Museum

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tions, coming as before from the wasting down of the mountain mass, continued to spread and increase on the pre-Badlands plain. And thus another series of rock layers, 250 feet or more in depth, was added to the steadily growing deposit. During all this time there was being preserved in these layers the fossil record from which we have been able to reconstruct much of the wonderful story of this region.

At the end of the second period something again happened to change the behavior of the rivers. We have no means of knowing exactly what this something may have been; but whatever actually took place, the fact is that for a time the streams cut their channels more deeply, and consequently lessened the effect of overflows at flood periods. Sedimentation on the surrounding plain practically ceased for a time, doubtless for many centuries. Then came another change, and deposition of river sediment was resumed. First the new sand and gravel deposits refilled the deeply cut channels, and then the periodical overflows were reestablished, and the building up of the surrounding plains was resumed.

During or immediately after the relatively brief period of channel cutting, a period which, however, must have extended over hundreds or perhaps thousands of years, two new and important migrants appeared on the scene, while some of the already established natives, among them the oreodonts and horses, so numerous in individuals and species up to that time, greatly diminished in both numbers and species. A few of the older types disappeared entirely, having died out or departed to other parts of the country. One of the new arrivals was an oreodont, a cousin of the merycoidodon, and it apparently outnumbered all the other animals of that region through the remainder of the upbuilding period. It was a queer little cud chewer, about the size of a sucking pig, with eyes placed far forward and so high as to be on a level with the top of the head—a feature which, with others, admirably

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adapted it to an aquatic life. These leptauchenias, as they are called, doubtless spent much of their time swimming about in the streams and shallow ponds with which the plains must have then been dotted. That an aquatic animal would have found a congenial home at this time is evident from the fact that the rock records of the upper zone furnish unquestionable indications that shallow lakes and ponds were unusually abundant.

The second of the late invaders—*Protoceras*—was perhaps the oddest of all the animals that lived on the pre-Badlands plain. Adults had about the size and proportions of a six-months-old pronghorn of our present western country. Something of both pronghorn and deer seems to have entered into protoceras's make-up; but the feet were quite unique among cud chewers in having four well-developed toes in front instead of the usual two characteristic of the entire present-day ruminant group, while the hind feet were of the modern two-toed type. But the most strikingly peculiar character of this animal is the extraordinary development of the head in the male. To begin with, he had a pair of horns placed above and just behind the eyes in the same position and probably of the same structure as the horns of the modern pronghorn. But, not content with this, he bore a small additional pair on top of the head just in front of the eyes, and a third and larger pair, of most peculiar form, on the slender muzzle. He also had a pair of long, slender tusks, slightly curved and flattened, like those of the saber-tooth, only more delicate. Teeth of this kind are not a common development among cud chewers, but, nevertheless, they are not unknown today, for they may be seen in the Asiatic musk deer, the Chinese water deer, and also in the very peculiar mouse deer of the Malay Peninsula, India, and western Africa.

What the habits of this *Protoceras*, or six-horned antelope, may have been is not quite clear. In a life restoration we have pictured these strange creatures in a mountain

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glade (Plate 82), and it has been assumed by some writers that they lived in the mountains rather than on the plains. The proportions of legs and body and the type of foot are admirably adapted to such surroundings, but, on the other hand, there is nothing in their structure that would exclude the possibility of their living on the plains. On the assumption that the mountains were their natural environment, it is not strange that their fossil remains should be absent from the widespread pre-Badlands deposits of that day—and they have not been found there; but it is puzzling to account for the fact that their bones are relatively abundant in the sand and gravel beds of the ancient-plain river forty and more miles from the nearest foothills. However, this peculiarity of fossil distribution might be explained on a theory of seasonal migration habits in these fleet-footed animals—habits well developed in our deer and pronghorns during their days of abundance before the West had been much disturbed by white men. It might then be true that while their summer habitat was among the beautiful parks and glades of the high mountains to the west, they were accustomed to wander far out into the plains country along the partially forested and brush-covered banks of the river during winter, remaining, perhaps, late enough in the springtime to crop the tender young grass or browse on the first buds, which burst forth at this lower altitude earlier than in the high country. Those individuals that died near the plains streams might have had their bones covered up and preserved, but those that died on the mountains would have left no trace. Another possibility is that the *Protoceras* was a strictly plains animal which happened to live in the region during the rather long period when the rivers were cutting and refilling their channels but were spreading no material on the plain. Under such conditions its bones could have been covered by sediment laid down in the channels, while no record of its presence on the level country would have been made.

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Following the arrival of these last new inhabitants of the pre-Badlands plain and the refilling of the ancient stream channels there began the last stage of the upbuilding work. Like the former stages, it was of long duration. Again century after century passed with no appreciable change in the general appearance of things. Except for the new arrivals that we have described and the disappearance of a few of the older kinds, the animals of the plains country were much the same as they had been throughout the preceding stage. But during this era no less than another two hundred feet were added to the formation's thickness, bringing it at last to a total of over six hundred feet.

When the pre-Badlands plain was completely formed its lateral extent was by no means limited to the local area that we have been describing. It reached far to the northward, where remnants of the deposit with its characteristic fossils are still to be seen more than a hundred miles away from the Big Badlands area. In the other direction its rocks can be traced south and west around the southern limits of the Black Hills into the region now known as the Hat Creek Basin country, where they disappear under the accumulated deposits of a later time.

Long though it may have continued, this closing stage of the plain-upbuilding work, like the earlier stages whose history we have traced, at last came to an end. The huge 600-foot-thick layer cake, spread over an area of several hundred square miles and holding within its substance the prizes that would one day be so eagerly sought by the fossil hunters, was at last completely formed. Nothing remained but to cut it. But before the streams began that cutting process which has fashioned the marvelous Big Badlands country of today and which, if no great earth change intervenes to stop it, must inevitably lead to the transfer of all the pre-Badlands plain material to the now slowly filling Mississippi Valley and Delta, a seem-



Restoration of the largest flesh eater of the pre-Badlands plain, *Hyænodon horridus*, an animal equal in size to a Newfoundland dog. It was probably a carrion eater, like the hyena, to which, however, it was only distantly related



Restoration of *Protoceras celer*, a distant relative of our pronghorn, about the size of a sheep. It was abundant near the end of the upbuilding of the pre-Badlands plain

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ingly interminable time period was destined to elapse. During this period the local forces of building up and tearing down were so evenly balanced that the pre-Badlands mass remained essentially unchanged save for the slow solidifying of its gravels, sands, and clays into rock and the equally slow process of complete petrification of the inclosed fossil bones. The duration of this era of balance can not be reckoned in years, but it was probably about ten times as long as the time span that extended from the depositing of the first titanotheres skeleton near the level of the old underlying sea bottom to the incasing of the last bones of a little aquatic ruminant in the pond mud of the topmost layer, more than six hundred feet above.

With the cessation of the last upbuilding period, the record of animal life on the pre-Badlands plain abruptly breaks off. Not one of the countless mammals which, since then, must have ranged over these uplands has left any trace. When they died, their bones, unprotected by mud or sand, soon weathered away, leaving a blank in the history of the animal life of this particular locality. It must not be understood, however, that we have no knowledge of the subsequent history of the general region, for not far away to the east and south the record was continued in another and later series of deposits more than twice as deep as those of the Big Badlands.

The tearing-down process seems not to have begun until some time in the epoch immediately preceding our own time, that is, in the Pleistocene, or "Ice Age." The date, therefore, may be set approximately at not more than a million years ago. The cause of this last greatest erosion period seems relatively easy to explain. It was certainly not due to any change of earth level that might have given a steeper slope to the beds of streams flowing eastward, for we find that the strata of the Badlands formation now have a slight but decided slope toward the Black Hills to the west. This dip, which could not have existed when the rocks were being laid down, was ap-

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parently caused by a later slight sinking of the Black Hills mountain mass. It must certainly have stopped the eastward flow of water across the plain, and it may even have produced a depression deep enough to hold a temporary lake. What actually occurred at this time, apparently, was that the Missouri River, which for ages had been cutting its valley backward toward the north and northwest, finally deepened its bed, in the region lying to the east of the Black Hills, sufficiently to cause the hitherto shallow-bedded and more or less meandering streams running into it from the west to take up in their turn the process of active valley cutting. In this manner the Cheyenne River, which had formerly been confined in a shallow valley lying to the north of our area, cut its present canyon southward across the Big Badlands region, capturing one by one the streams that in the times of the Badlands upbuilding had flowed eastward into the Missouri. This large-scale river-channel cutting was the main factor in producing the topography that we now see.

In writing this bit of history, we have made no attempt to give complete lists of the animals found at each succeeding period. Neither have we tried to follow in detail the sedimentary changes revealed by a technical study of the rocks in which the Badlands fossils lie. We have wished merely to trace the main line of events over a great period whose record is peculiarly complete. By the reading of this one local record we have hoped to give a clear idea of the methods that are being used by paleontologists in attempting to piece together the history of ancient life as it is chronicled in the rocks of every part of the world.

CHAPTER III

HOW EXISTING MAMMALS ARE COLLECTED

FIELD work on living mammals is a very different matter from field work on fossils. Both pursuits take the collector out into the open, but there all similarity between them ceases. Fossils are already dead and preserved; living mammals must be killed and then with all haste made into museum specimens before decay ruins them. Fossils cannot move about. When once found they may be carried to the museum piecemeal at the collector's convenience. Living mammals are constantly active, and it is only by learning to know and to follow their movements that the collector can hope for success in finding them. And, last of all, fossils, of themselves, give no indication of their whereabouts. Unnumbered myriads of them lie concealed beneath the surface of the earth. There they will remain until they chance to be exposed by the action of natural forces, such as stream cutting, or by human activities, such as quarrying, mining, road building and foundation digging. Living mammals, on the contrary, often force the attention of everyone to their presence by large size, loud voice, or conspicuous behavior. Or, when the animals themselves keep hidden, as is the case with most of the smaller kinds, they usually make their whereabouts known by leaving behind them a record of their activities: a path or runway through the grass here; a tunnel under rotting leaves there; footprints in snow, mud or sand; holes and mounds that tell where some creature has been digging for roots or grubs, or to make a shelter; piles of the

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emptied shells of seeds, nuts, snails, mussels, or crayfish; in short, a complicated code of signs unwittingly laid before the collector for his guidance.

To obtain specimens of the larger mammals it is necessary to go into the field armed with gun and rifle and to adopt the methods of the sportsman. These methods are so well known and they have, moreover, been so often and so fully described in books of travel and sport that we shall not spend any time on them here, but shall proceed at once to the less familiar subject of collecting the smaller mammals.

Small mammals, by which we mean the kinds of lesser size than those popularly recognized as "game," can not be systematically collected without the use of traps. Mice and shrews may, it is true, often be induced to tumble into pitfalls dug in places where such animals live, and under special circumstances some of the smaller ground-living rodents can be successfully obtained by the use of poisoned grain. But the experienced collector always goes into the field with an assortment of traps specially selected for the capture of mammals of the most varied kinds and for service in the most varied situations. To use traps effectively he must exercise his ingenuity and apply his knowledge in deciphering the records to which we have just alluded—records which, if correctly interpreted, will point the way to success, but which, if misunderstood, may lead to amusing failure; for example, on an occasion when one of us caught nothing but large insects (mole crickets) after laboriously setting many "cyclones" in tunnels that he wrongly supposed had been made by small shrews.

The elements of uncertainty and surprise that accompany the trapping of small mammals give it a charm and interest quite its own, and entirely different from the excitement that attends the hunting of larger creatures, which can be deliberately sought, seen, and shot. From time immemorial the joys of the chase have been told by



Cow and calf elk, showing distinctive color patterns in each. Distinctive color patterns in adult and young are common among deer and occur also in some kinds of pigs and cats, although they are rare in mammals as a class

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men of letters; but we have been able to find only one attempt by an artist of the pen to convey to others the thrill that can come from a few dozen prosaic mouse traps knowingly placed in meadow and wood.

In an almost forgotten book, "At the North of Bearcamp Water," published nearly forty years ago, Frank Bolles recorded his impressions as he followed his trap line through the mountains near Chocorua, New Hampshire. The chapter entitled "Trapping Gnomes" is so remarkable for its vividness and for the unusual nature of its subject that we shall reproduce part of it here, taking the liberty of making a few alterations in names.

When the harvest moon is large and the nights clear, I love to spend an evening hour or two under the great oak-trees on the shore of my lonely lake. The soft mists creep across the water, bats flit back and forth squeaking, the whippoorwills call to each other that the time for migration is near at hand, and sometimes the voices of the barred owls wake weird echoes in the lake's curves. Sitting motionless in the black shadow, I am unseen and unsuspected by the night creatures round me. Many feet move upon the dry leaves, and the fluttering of wings disturbs the still air. Measuring the evening from sunset until ten o'clock, it seems a period of more activity than the day. Hours roll by in the September sunlight with scarce a sign of life near the lake, but the coming of twilight is a signal for awakening. . . .

In these hours the ground gives up its cave dwellers, and their soft feet rustle the leaves in all the forest and by every brookside. . . . It is neither fox nor skunk which makes the soft pattering just behind the old oak against which I lean. A smaller wanderer than they comes there, and as surely as gnomes have settled in America this must be one of their haunts. I feel certain of it when a squeaky little whisper follows the pattering, or when occasionally a tiny form darts across a patch of moonlight near the edge of the water.

In these September hunting-days I have left the grouse to feed undisturbed among the blackberries, and the hare to dream away the sunlit hours in his form among the swamp evergreens. Mouse-hunting has been my pastime, and so low is our human estimate of the character and usefulness of these tiny creatures that my conscience has not given the faintest bit of a twinge when I have brought home dead mice from field, meadow, mountain, and forest. Our mice are not all of one kind, and when I started with my game bag in the September sunlight I did not feel sure what manner of elf I might bring home with me.

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Setting out early on the morning of the 12th, I dashed the dew from the brakes as I crossed an open pasture on the way to my lonely lake. The brakes were growing brown, yet we had had no frost, and the equinox was still ten days distant. The sumacs were gorgeous in green, scarlet, and orange, waiting for the first rain or wind to hurl to the ground half their gay leaves. . . .

Just beyond the sumacs is the stump of a prehistoric pine. It has lasted generations since its towering pillar fell and sank year by year deeper into the soil. Its hard gray walls look as though they might endure half a century more of snow and sunshine. Mice live under that stump, and the first of my traps was set at their cave archway. Kneeling down behind the clustering blackberry briers, I could see the archway just at the head of the opening between two of the great buttress roots of the stump. Moss was growing at the threshold, ferns overhung the doorway, and a tiny path led through the grass from the arch into the dry pasture beyond the briers. Yes, the trap had been sprung, and crushed beneath its cruel springs was a gray mouse. His eyes were large and dark. His coat was of soft gray, and his waistcoat snowy. His hands and feet were very white and his elfin ears mischievously large and erect. The book name of this white-footed mouse is quite musical—*Hesperomys*, the evening mouse [now *Peromyscus*, literally, the "little pocket mouse"].

In a deep hollow between wooded banks runs the pasture brook. It comes from the forest-clad mountain-side, and flows to a dark swamp, beyond which is the lake. Mice live by the brook, both in the hollow and in the swamp. Nine traps were set in the hollow and eighteen in the swamp. These traps are, with true Yankee originality, named "cyclones," and they are nearly perfect as engines of destruction. Upon a small square of tin are hinged two rectangles of stiff wire, so attached to strong springs that they naturally lie flat upon the square of tin. One rectangle is smaller than the other so that it just lies within it. The trap is set by raising the rectangles until they make a tent-like frame, and then securing them by a catch. The best lure for mice is whole corn, which is placed near the centre of the square of tin in a tiny cup suspended by a lever to the catch which holds the trap open. The mouse steps softly through the wire rectangle and tries to lift the grain from the cup. Woe to him if he presses ever so lightly upon the side of the cup, for if it is depressed, and the other end of the lever moved, the catch is cast free and the rectangles fall together with such force as to crush any small creature which stands below them.

The nine traps set by the brook were in groups of three. As I drew near the first group, I looked for broken twigs and a scrap of white cotton tied to a branch, my signals to show where the traps were placed. Bent twigs with their leaves slightly withered and drooping

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are readily seen at a long distance. The first three traps were set at a point where the banks of the brook were steep, and the level moss near the water only a narrow belt. At one place a mossy log crossed this level, a mouldering stump crowned with ferns flanked it, and a big boulder raised a wall of granite parallel with the stream. Just across the brook was another long log covered with moss, violet leaves, and rue. One trap was on this log, one by the boulder close to a little hole running under it, and the third near the mouldering stump. At first as I stood in the midst of the traps I could see none of them. The corn scattered near had been carried away or eaten, and the strings by which the traps were tied to stakes were not where I remembered to have left them. Suddenly I saw one trap. It was sprung and drawn away among the leaves. Something was in it, something I had never before seen, a creature more beautiful than any squirrel, as graceful as a swallow and as suggestive of speed and lightness. I knelt over this slender, brightly-clad mouse and released his lifeless body from the trap. His cobweb-like whiskers were wonderfully long, his coat was of pale straw color and brown, his waistcoat of purest white. No monkey has a tail proportionally longer than the seemingly endless white-tipped appendage of *Napaeozapus insignis*, this woodland jumping mouse of the mountain streams. Exquisite creature, I thought, how can I have lived so long among woods and brooks without suspecting your presence? But for a "cyclone" I might never have known that such a being existed.

The other two traps were sprung, one containing a second *Napaeozapus*, and the third a gray *Peromyscus*. Similar fortune had attended the remaining traps by the brook, three containing specimens of *Napaeozapus*, two of *Peromyscus*, and one a large mole with fur as fine as the softest silk velvet. I pushed on eagerly to the series of traps in the swamp. . . .

The first of the second series of traps was set on the slope leading down towards the moist bed of the swamp. It contained one of the white-footed gray mice. The next three were empty. Number five was in the darkest part of the swamp on a huge upturned stump whose twisted roots, looking like the arms of a devilfish, reached far into the air. The trap was sprung, and the mouse in it was as new to my eyes as *Napaeozapus* had been. Coarse, chestnutbrown hair, in parts almost as bright as red mahogany, small eyes, conspicuous ears, and a tail so short that it seemed only a stump of something more satisfactory, were the conspicuous points in this mouse. His name, I later learned, was *Eutamias*, the red-backed mouse. His rich coloring matched to perfection the decayed hemlock stump in which he lived, and harmonized with the brown bark of pines and the stained waters of the swamp brooks. In the sunlight, or upon the sand by the brook-

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side, he would have been conspicuous. Where he lay he looked like a fragment of the reddish wood under him.

Five more of his tribe, and a tiny shrew, only three inches long, were found in the remaining swamp traps. One of the mice had been nearly devoured as he lay in the trap, the parts remaining being skin, feet, tail, and a small portion of the head. I suspected a big mole of being the ghoul. On my way home I looked in a trap set under a small foot-bridge which spanned a damp spot in a mowing-field. The victims here—for two had been caught at once—were of the family *Microtus*, the sturdy small-eared mice of the fields. Their eyes were very small, their ears almost concealed by their coarse, dark-brown hair, and their bodies awkwardly but strongly built.

Very different and no less attractive to the man over whom the mysteries of nature exercise their sway is the pursuit of the mammals that range at night through the tropical forests. Little or nothing of these animals can be seen except the reflected glow given off by their eyes as the hunter explores and feels about in the enormous darkness with a slender beam of artificial light. Mr. E. A. Goldman, who has had much experience in Mexico and Panama, has generously prepared for us a first-hand account of collecting mammals at night. We give it here practically in his own words:

Any one suddenly enveloped in the full glare of light from an automobile can perhaps understand the helplessness and confusion of wild creatures when exposed to the concentrated rays of a good hunting lamp, or so-called jack light. Reflections from the eyes of many animals commonly glow like balls of fire, but in different kinds of animals the exact color of the reflection varies from flame to greenish or bluish. These reflections from the eyes may be seen much farther away than it is possible to discern the outlines of the body. If no noise is made by the hunter the bewildered creatures often gaze stupidly at the light and permit a very close approach. When the light is properly placed, preferably on the hunter's head, the gun sights are clearly seen and accurate aim is easy.

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My earliest first-hand knowledge of the use of a jack light came from native hunters during field work in Mexico many years ago. Very primitive hunting lamps were made by cutting a round hole in the side of a metal can and placing a candle inside. This improvised light was carried on the head, usually attached to a pad made for the purpose. Such short-range lights, of course, had a very limited use, but native hunters, accustomed to them and moving very slowly and quietly, were able to kill deer, agoutis, pacas, rabbits, and many other kinds of game.

In most of my later work I used an acetylene lamp, with a carbide receptacle attached to my belt and a tube carrying the gas to a light-weight burner and reflector fastened to my hat. Modern, focusing flash lights have some advantages over acetylene lamps, as they are simpler to use. The flash light may be carried on the head or held in the hand alongside the gun barrel in firing. Skill in the use of jack lights is acquired through experience just as in other forms of hunting. The beginner is sure to be confused by the teeming night life of the Tropics and the many points of light that flash back in response to his moving "jack." Surprisingly bright gleams come from the eyes of spiders, land crabs, and large insects, but these he will soon learn to recognize by their small size and peculiar diamondlike quality. Most of the night animals can be identified in a general way by the size and color of their eye reflections or the distance apart at which the two reflections stand; but there is always an exciting sense of uncertainty, and beginners should be cautioned against the danger of shooting domestic animals. Fortunately, human eyes do not "shine."

How a beginner may unwittingly get into trouble was shown by my first experience in hunting with a light, an experience that served as a salutary lesson and one that I have often recalled with amusement. Near San Benito, on the Pacific coast of southern Mexico, I found, one day, tracks and other signs showing that a very large cat,

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apparently a jaguar, was making repeated nightly patrols along the shore and feeding on the eggs of sea turtles deposited at frequent intervals in the loose beach sand above high-tide mark. Here evidently was an opportunity to try my new light. That night I had proceeded about two miles when, on rounding a point, I saw a pair of eyes shining very brightly at about the right height to be those of a jaguar. As they did not move I advanced slowly with my rifle sights bearing steadily on a point between them, ready to press the trigger if the animal should make any movement. I was about to fire when my light revealed the outlines of the owner of the eyes. To my astonishment I saw, instead of the most dangerous Mexican beast of prey, ready to spring upon me, only a peaceful horse quietly lying down. Startled by the realization of what a mistake I had almost made I returned to town thoroughly disgusted. Why a horse should have been reposing on that lonely beach I could not imagine; but it should have occurred to me that no cat could have such large, widely spaced eyes, nor could any cat be expected to stare fixedly at my light, as these animals are so restless that they seldom give the hunter more than a fleeting glimpse of one eye.

The constructing of the Panama Canal brought together many American hunters, some of whom, in spite of their inexperience, wished to try their luck at jack-light hunting under the new and strange conditions. I was told that there were several untoward incidents: A mule tied to a post in front of a house was shot; a domestic cat, sitting within a few feet of its owner in front of a small shack at the margin of a heavily shaded forest trail, had all of its nine lives snuffed out. Public opinion became so aroused that all jack-light hunting in the Canal Zone was forbidden by Executive Order from Washington.

In connection with field work in Panama beyond Canal Zone limits I was very successful in using a jack

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light. Specimens of a number of mammals, including a rare and little known member of the raccoon family, could be taken only in this way. I hunted by following the trails that cross the open savannas and penetrate deep into the forests, or by quietly paddling a dugout canoe along the shores of streams. Often while intent on the search for other game, I saw in the water close to my canoe the fiery red eyes of crocodiles.

Although one finally learns to recognize the eyes of some animals, an element of uncertainty always remains. When hunting at night on the savannas in Panama I was never able to distinguish the eyes of rabbits from those of the parauque, a large goatsucker which was a common bird there. Both rabbit and bird have eyes that give off a bright red glow, and the eyes of both are set about the same distance apart and are of about the same size. I repeatedly fired at what I thought was a rabbit only to find I had killed a parauque. Hunting at night in this region is a fascinating sport, its charm being largely due to the almost constant feeling of uncertainty as to what the animal behind a particular pair of eyes may be. This is especially true of arboreal species. One sees a pair of eyes, or perhaps gets a glimpse of only one eye which may or may not be moving about. At the report of the gun something comes thrashing down through the branches and brings up on the ground with a gratifying thump, and one rushes in, keen to discover what he has added to his collection. It may prove to be a kinkajou, perhaps the most abundant arboreal mammal encountered at night, or a raccoon, or the raccoon's relative, a *Bassaricyon*. There is also the chance that the victim may be one of the soft-furred, owl-eyed, night monkeys, or perhaps a carnivore such as the martenlike tayra or one of the smaller cats. One night while maneuvering about under a tree trying to get a shot at an eye that I thought I saw moving among the foliage I fired at a star!

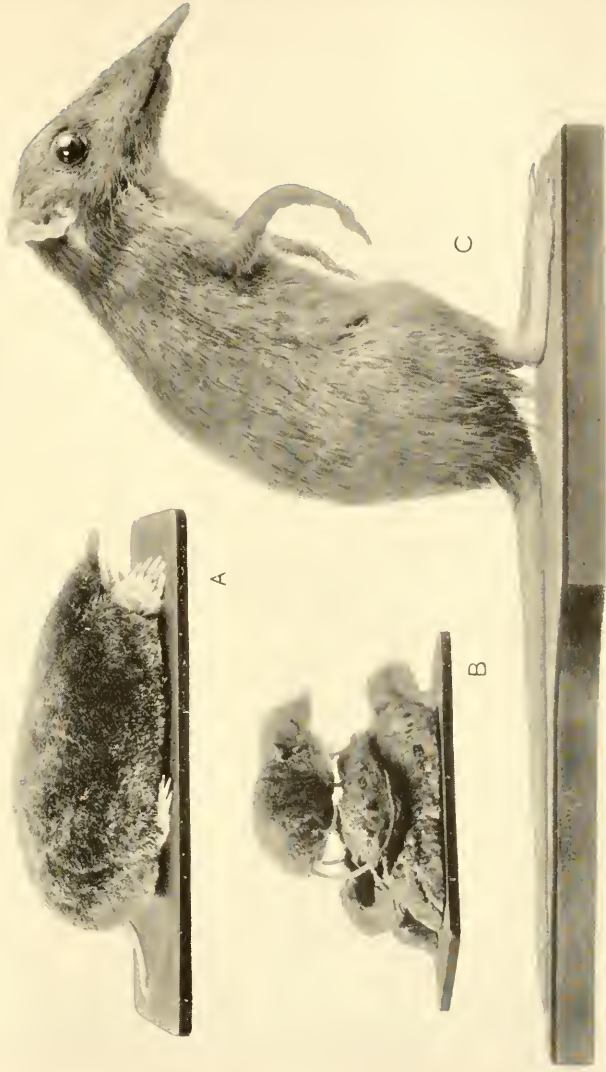
Returning now to the ordinary methods of collecting

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we find that the smaller mammals usually have two characteristics on which the collector relies in the pursuit of his calling. They can be lured to the trap by bait or by attractive odors; and, in the course of their regular daily or nightly activities, they habitually follow definite paths or "runways," in which traps may be placed to good advantage without bait. A representative series of most of the small mammals living at any one place may usually be had in the course of a few weeks' skillful exploitation of these two characteristics.

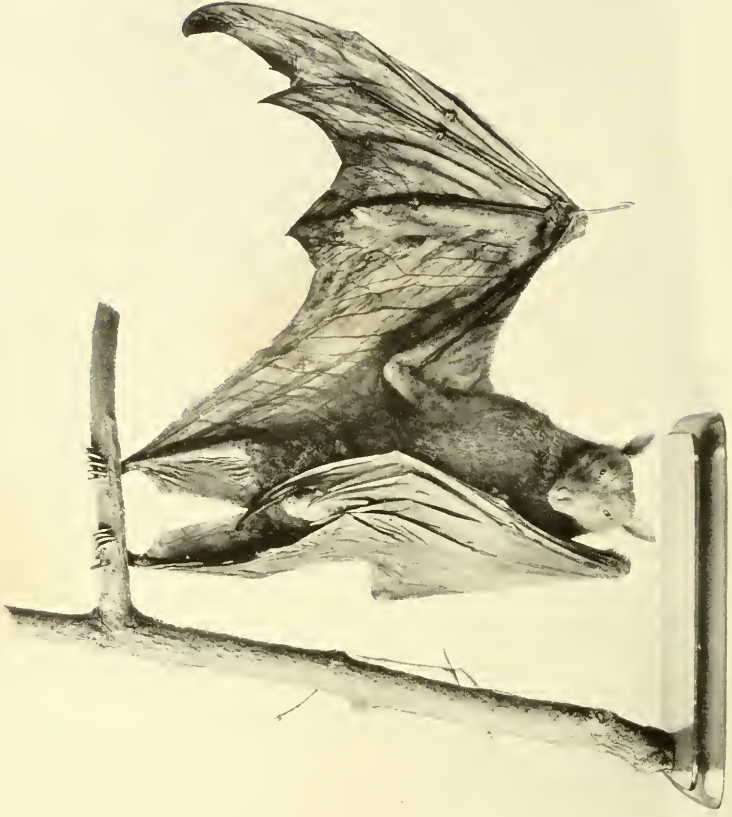
But there is one very widespread and very interesting group of mammals—the bats—whose members elude all methods based on lure and runway. Bats must be sought in caves, old buildings, and hollow trees, where they sleep by day, or they must be shot during the short period of fading daylight that follows their emergence at evening in quest of food. At best this period may last for half an hour, and it may be as short as ten minutes. And much of it will probably be spent in finding the bats that fall to the ground after being shot. For the great difficulty in bat shooting is to calculate distance. In the fading light objects appear much farther away than they are, so that one is constantly overshooting and overestimating the distance at which the prey falls.

However they are obtained, mammal carcasses must be made into museum specimens soon after death. Otherwise decay will set in and the results of much hard work will be lost. As most of the small mammals are nocturnal, a collector ordinarily visits his traps in the morning, and, in a warm climate, as early as possible, before the heat of the day has begun. This is the time when the most interesting and unexpected captures are usually made, as they then consist chiefly of creatures that keep themselves well concealed by day. Frank Bolles's experiences with his first woodland jumping mouse and red-backed mouse were of a kind familiar to every field man. Often a visit to the traps in late afternoon or early evening will



Three insectivores

A, mole; B, one of the common shrews; C, African jumping shrew. The mole's feet are greatly enlarged for burrowing. Specimens in the National Museum



A large Malayan fruit bat, or flying-fox. Its wing spread is about four feet. Specimen in the National Museum

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be profitable, as there are some mammals, like chipmunks and field mice, that habitually forage by sunlight. When a collector has worked so long in one place that his traps cease to make unfamiliar captures he concludes that he has a good representation of the mammal life of that particular place. He therefore moves on to a locality where differences in soil, vegetation, or climate give promise that other kinds may be found. In this way he gradually makes a systematic survey of a region.

As soon as they are brought in from the traps, the specimens, or most of them, are prepared by removing the skin and drying the skull or skeleton, as these parts serve the most useful purpose in the subsequent studies. Usually, however, a few individuals (of bats and shrews in particular) are preserved entire in alcohol or formalin. Skins of small mammals, up to about the size of a house cat, are stuffed to natural size with tow or cotton, wires are inserted in the legs and tails for stiffening, and the cut on the underside through which the body was removed is sewed up. The specimen is then carefully smoothed out in a conventionalized but nearly natural form, and is finally dried lying flat, back up, with the fore legs extending alongside of the neck and the hind legs drawn backward parallel with the tail. Preservation in this uniform manner is essential to the comparison of specimens with each other and also to their convenient keeping in cases fitted with shallow drawers or trays. Larger skins are first salted and then cared for in any way that may be convenient until it is possible to tan them. Each skin, whether large or small, is labeled with locality, date of capture, name of collector, and a serial number that serves to identify it with the corresponding skull or with any other parts that may have been kept. Great care must be exercised to insure perfect drying of skins and skulls before they are packed for shipment home to the museum, as dampness inside of a tight box may cause irreparable harm.

CHAPTER IV

MAMMALS IN THE MUSEUM

INTERESTING and important though it may be, field work is only the beginning of the real study of mammals. To complete it and to give it the definite form needed to make it a special, organized department of learning we must further pursue this study in museums. The name of this branch of learning is mammalogy, and its aim is the systematic study of the Mammalia—the gathering and orderly arranging of facts about the animals that, at least during some stage of their existence, grow hair and secrete milk.

The word *mammalia* appears to have been first used about the middle of the eighteenth century, by the Swedish naturalist, Carl von Linné, better known as Linnaeus. Strange as it may seem, there had not been, up to that late day, any distinctive name for the designation of the great assemblage of animals to which we ourselves belong, together with our relatives—such as the whales, duckbills, bats, apes, and many others—whose most obvious group characteristic is that the young must be fed on milk. The term quadruped could not be used, for this is equally applicable to the hairless, milkless lizard and tortoise. Linnaeus therefore took the word *mamma*, the Latin name for the gland that secretes milk, and telescoped it with another Latin word *animalia*, meaning “animals.” The result was *mammalia*, shortened from *mammanimalia*. We, in English, have made from Linnaeus’s technical term the vernacular word *mammal*; by adding a Greek termination meaning “discourse” we

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have further produced the English name *mammalogy* for the technical study of these creatures. Other peoples have not followed our example. Instead of using some form of the Linnaean word, the French, for instance, have preferred *mammifères*, that is, "bearers-of-milk-glands," while the Germans say *Säugethiere*, or "beasts-that-suck." All the main European languages agree, however, in using some term that alludes to the presence of milk.

In its technical sense the word *mammalogy* is commonly applied to what is known as the systematic study of mammals; that is, to investigations whose main object is to find out exactly how many kinds of mammals there are and have been in the world, exactly where each kind lives or has lived, and exactly what are the relationships of all these creatures to each other. Among the mammals known from fossil records only, there are many kinds that appear at first sight to be so strange as to seem quite unlike all living creatures; but, though the records fail to give direct evidence that these animals had either hair or milk, they present us with unmistakable characteristics of bone and tooth, by means of which the true classification can be firmly established.

On the face of it, the task of mammalogy as thus defined may not appear to be a large undertaking. The average person not specially interested in wild life may be acquainted with as many as twenty or thirty different kinds of mammals; or, if he lives near a good zoological garden, with fifty or seventy-five. Of fossil mammals he may know the mammoth and mastodon and may have the vague idea that there were once some other great mammalian beasts that are now extinct. Actually in North America alone we have discovered about 5,000 recognizably distinct living and fossil kinds, and the work of enumeration is not yet finished; from an area in eastern Africa scarcely one-tenth as large as North America, the collections of the Smithsonian Institution include representatives of no less than 526 living kinds

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of mammals, all of them different from those found in any part of the American continent. The Malay region, with its innumerable islands, and South America, with its astonishingly contrasted jungles, plains, and mountains, swarm with special sorts of mammals whose existence is unsuspected by any one not a student of the subject.

When the count is completed, the total number of species and subspecies of living mammals in the entire world will possibly be found to exceed 20,000. We must now imagine behind these living mammals long lines of extinct ancestral and related species reaching into the past and preserved as fossils. Every new discovery in the seemingly exhaustless deposits of extinct mammals increases the number of these lines, and makes the excessively complicated nature of the subject more apparent. At present it is not possible to take an exact census of the known fossil mammals, but a review of the literature convinces us that the total number of those described up to 1930 must be not far from 10,000, half of which, at least, have been discovered during the present century. Keeping in mind the extreme incompleteness of the fossil record, we must realize that this total represents only a minute fraction of the entire number of mammals that belong strictly to the past.

As soon as the specimens are received at the museum it is necessary to arrange them so that they may be available for study and safe from the danger of deterioration. To begin with, they have to be catalogued, numbered, and labeled in accordance with a system by which every separate part preserved—skin, skull, skeleton, or any of the soft parts that may have been placed in alcohol—can be identified as having come from a given individual. Here the work of special cataloguers is needed. Skulls and skeletons of freshly killed mammals are next put through processes by which their dried flesh is removed; while fossils are “developed” by chiseling away the stone “matrix” in which they are usually embedded, as



Pacific walrus, as mounted in the National Museum. The walrus uses its tusks to dig for clams and scrape mussels off rocks



Giraffe and okapi, as mounted in the National Museum. (In case at right are zebras.) The horns in both these animals have a peculiar structure consisting of a bony core covered with skin. The giraffe inhabits open scrub country; the okapi, dense forest

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well as by assembling and putting together the fragments into which they are often broken. All this requires the services of highly skilled preparators. When finally ready for permanent installation in the collection the smaller bones are placed in glass tubes or pasteboard boxes, the larger ones in trays or drawers; then all are arranged in cases according to some scheme of classification that will permit the ready finding of any individual specimen needed for examination.

Contrary to general belief, the specimens on exhibition do not constitute the real collection. The main object of a great museum is to promote research; that is, to advance our knowledge of the world we live in, and not merely to display beautiful examples of the taxidermist's art. Research requires an abundance of material in convenient form for study—a requirement that a few mounted specimens locked in glass cases can not fill. The exhibition series of living mammals is therefore nothing more than a group of selected individuals that can be spared from the real collection. We say *spared* because practically every skin that is mounted and placed on exhibition is condemned to death from the slow but inevitable ravages of time and sunlight. The conditions as regards fossils, however, are somewhat different. Such material does not deteriorate from exposure to light; and the examination of a specimen, particularly a very large one, is often facilitated by having the parts put together in their natural positions. Mounted fossils are, therefore, of relatively greater technical value than mounted skins.

The study series, as the real collection is called, is kept in wooden or metal cases where the specimens will be as safe from deterioration as human ingenuity can make them. In the United States National Museum, which is under the direction of the Smithsonian Institution, there were in June, 1930, about 217,000 specimens of the now living, or Recent, mammals in the study collection, while those on exhibition totaled barely 1,400. Of fossils there

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were about 25,000, including about 160 specimens on exhibition.

Study of a mammalian collection, whether modern or fossil, requires as a first step the classification of the material by orders; that is, determining whether a given specimen represents, for instance, the great group of hoofed mammals (ungulates), or the flesh eaters (carnivores), or the gnawers (rodents), or the trunk bearers (elephants), or the true flying mammals (bats), or the fish-like mammals (whales and porpoises). Next the specimens are sorted out into the successively smaller subdivisions of each order; that is, into families, as, among the flesh eaters, the bear family, cat family and dog family; into genera, as, in the dog family, the true dogs, the foxes, the fennecs, and the African hunting dogs; and into species, as the dog and wolf (two species of the true dogs as distinguished from the foxes, fennecs, and African hunting dogs). Finally each species is separated into its subspecies, or the local forms that it assumes in different parts of its range, as the huge wolf of our northern forests, the smaller wolf of the Arctic tundras, the dark-colored wolf of Florida, and so forth.

Subspecies, as we understand them, are distinguished from each other chiefly by size, by shades of color, and by slight peculiarities in the proportionate lengths of various parts (feet, ears, tail)—usually small differences not involving deep-lying elements of structure, and, more important still, not always present in every specimen. Species are determined by constantly present peculiarities of the same general kind—possibly greater in degree than those that distinguish subspecies—and by differences in actual color and in color pattern, quality and distribution of the fur, shape and size of the teeth or of the individual parts of the teeth, and shape and size of the individual bones of the skull. Genera are determined by still greater peculiarities in structure, often including differences in the number of teeth, the number of toes, and so forth, the

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essential feature of a genus being that it includes a group of species either actually or as a reasonable possibility. Families are determined by larger characters of the same kind as those that distinguish genera, and each family is primarily a category that includes or might include a group of genera. Finally, the orders of mammals are distinguished from each other by various combinations of the largest and most fundamental characters of all, such as the processes of reproduction, the type of the limbs and feet, and the type of the teeth. In dealing with the classification of fossils, external characteristics, such as color, hair, ears, and tail, are of course out of the field of consideration. The skeletal parts, then, furnish the only peculiarities by which the animal can be classified; and the structure of the feet, teeth, and skull are therefore the only features that may be depended upon for classification.

Systematic mammalogy, therefore, resolves itself into the investigation of all these features and of any others that may assist in the accurate determination of the different kinds of mammals, and in the grouping of these kinds according to their relationships. As a preliminary to work of this kind it is of prime importance to distinguish between peculiarities that are specific or racial and those that are mere individual features—of the sort normally occurring in one or the other sex and at one or another of the various ages of the same species. Many specimens of each species of mammal must be examined and compared before the differential peculiarities can be clearly distinguished from those belonging among the diverse sorts of individual variation. Many more are required to determine the status of subspecies or local races, because a series from one place may be obviously different from a series from another, in which event a comparison of only one or two specimens from each place would be indecisive. And still more specimens of each living kind are needed from as many different localities as possible, and of each fossil species from every rock layer that can be ex-

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amined, in order to determine the limits of range in both geography and time. Complete specimens of fossil mammals are rarely found, many species being based on small but characteristic parts of the skeleton, as the teeth and jaws. For fossils, then, a far greater number of specimens is required than for living species to determine the limits of individual differences. Field observations of living wild mammals, such as those that have contributed to our knowledge of birds, are unfortunately of little value, because so many of the most interesting mammals keep themselves hidden from human sight.

In mammalogy, as in every other branch of present-day knowledge, an important element in the routine of the active worker is the task of keeping abreast with the ever-increasing flow of literature. Arising from the work of museum staffs and of individual students, given out through the channel of books, periodicals, and the journals of scientific societies, finding its source in the two Americas, in England, France, Spain, Belgium, Holland, Denmark, Norway, Sweden, Germany, Italy, Hungary, Russia, the Malay States, Java, Australia, China, and Japan, there flows a growing stream of publications about mammals, living and fossil. To be ignorant of the information that these treatises, monographs, papers, and notes contain would be a fatal handicap to any one who aspired to become a serious student.

The beginning of mammalogy dates from the middle of the eighteenth century. At that time two naturalists, Linnaeus in Sweden and Brisson in France, gathering together and summing up the knowledge of vertebrates that had been accumulated during two and a half centuries of world exploration, laid the foundation on which the present structure has been built. Much information had already been published, but the definite course of procedure that we are following today was not established until Linnaeus perfected his system of classification and nomenclature and Brisson applied to mammals his



Striped hyena, one of Africa's bone-crushing scavengers. Specimen in the National Museum



Lions. Collected in 1909 by the Smithsonian-African Expedition under the direction of Theodore Roosevelt.
Group in the National Museum

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enlarged scheme of synoptically tabulating the characters by which the different groups are distinguished from each other. Trivial though such innovations may appear, they actually proved to be of so much importance that mammalogy as a special branch of zoology took its date from them, and the work of earlier naturalists retired to a position of antiquarian interest. The reason for this should be apparent to any one who has grasped the idea of the great number of mammals to be written about: the appearance of any convenient scheme for handling the rapidly increasing mass of facts, when hitherto no such scheme had existed, would necessarily mark an epoch. The system of Latin names perfected by Linnaeus and regarded by the general public as a means of mystification is actually a timesaving device, a tool so useful that, in the absence of something better, the scientific study of mammals could not have gone on without it. The same may be said also of Brisson's system of tabulation.

In the year 1758 Linnaeus was able to enumerate only 86 species of living mammals in the tenth edition of the *Systema Naturae*, his boldly conceived two-volume review of the living things of the world. A century later Spencer Fullerton Baird, the second Secretary of the Smithsonian Institution, knew 220 living kinds in North America alone; while now, 70 years after Baird and 170 years after Linnaeus, we are acquainted with about 5,000 kinds, rather evenly divided between living and fossil, in North America, or nearly seventy times as many as the whole world was supposed to contain at the time when the real study of mammalogy began. To trace all the steps by which this increase of knowledge has been made would fill an entire book. Here it will be possible merely to indicate some of the most important.

At first the subject matter of mammalogy was so small that every author felt himself qualified to describe all the mammals in existence. This feeling of self-sufficiency

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arose from the then prevailing ignorance. There were very few mammals known to write about, and the system by which these few were classified was so simple and artificial that there was no difficulty in referring each species to its proper place in an author's scheme of classification. Great museums had not been established, and especially equipped collecting expeditions to hunt and trap living mammals or to dig and quarry fossils were undreamed of. The descriptions and notes made by travelers and published as incidental matter in their accounts of strange lands were the chief sources on which the European naturalists were forced to depend. Work done under such conditions was absurdly incomplete, but it was highly satisfying in its appearance of finality. Indeed, the complicated nature of the facts could not have been suspected by the early workers. It was therefore possible for these men to regard each species and each higher category as an entity unconnected with any other except in the sense that the members of a lower category might be looked upon as so many examples of the type represented by the larger group to which each belonged.

To illustrate: Lion, tiger, and puma were examples of the cat genus; the cat genus, dog genus, and bear genus were examples of the carnivore order; the carnivore order, rodent order, and bat order were examples of the mammal class; the mammal class, bird class, and reptile class were examples of the animal kingdom. There was no thought of actual relationship by the bonds of common descent, no suspicion that the boundaries supposed to separate species from species or order from order might not always have been as sharply drawn as they appear to be now; in a word, there was not the slightest inkling of the true scope and nature of mammalogy. For these early investigators the animal kingdom was a definite and finished product, a thing made up of parts as distinct from each other as the stones in a wall. When once these parts had been found, catalogued, and described, the

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work would, it was thought, be complete. Under the influence of conditions and conceptions such as these it was natural that books on mammals should follow the Linnaean precedent of concise synoptical treatment, briefest possible description, relatively elaborate citation of the work of previous authors, and absence of discussion or speculation as to the meaning of the things that were being catalogued. Books of this general type were published in France, Germany, Holland, and Russia.

The period during which the writing of all-inclusive works on the species of mammals by one man was supposed to be possible came to an end, however, before the middle of the nineteenth century.¹ Since that time the largest units of publication have been monographs of single orders, enumerations of the species of mammals known to occur in limited areas, and treatises on the classification of mammals at large with discussions of the derivation and interrelationships of the higher groups. During the past forty years a type of publication that was comparatively little known before 1850 has become dominant; namely, the short paper containing descriptions of a limited number of newly discovered mammals, lists of the species found in particular regions or in particular rock formations, or the elucidation of special, limited problems of structure, classification, distribution, or relationship.

After this brief general survey of the entire field of mammalogy, we are prepared to look more closely at the special history of each of the two main branches of the subject, namely, the study of fossils and the study of the mammals that are living in the world today.

¹A summary of the study of mammals during the 140 years following Linnaeus was completed in 1898 by Dr. E. L. Trouessart, of Paris, under the title "Catalogus Mammalium tam Viventium quam Fossilium." It enumerates 4423 supposedly different kinds of living mammals and 4494 fossils, and gives references to publications describing each. Since then not less than 8700 new names have been added to the list of living species and subspecies and not far from 2000 to the list of fossils; and discoveries continue at the rate of about 300 a year.

CHAPTER V

HOW MAMMALOGY BEGAN AND GREW

THE oldest record of a fossil collected by civilized man apparently dates back more than four thousand years to a flintlike segment of a plant stem placed as an ornament on an Etruscan tomb, and now preserved in the Capellini Museum of the University of Bologna. Much later, probably in the time of Hippocrates, about twenty-three hundred years ago, a tooth of an extinct elephant was found by some Greek, and was possibly handled by the philosopher himself. The rediscovery of this tooth was made only recently and in a quite accidental manner. During a collecting trip in the interests of the American Museum of Natural History, Mr. Barnum Brown found the tooth where it had been excavated, together with pieces of statuary, from among the ruins of the ancient medical temple, the Asklepieion, on the island of Cos, in the Aegean Sea.

From the early part of the Christian era onward through medieval days, fossils occasionally attracted the attention of European philosophers, historians, doctors, and others. Such remains were usually those of large mammals, like elephants or cave bears. They were often believed to be bones of huge men; and it is said that some of them were, therefore, piously reinterred. That they have been the source of some of our legends about dragons and giants is highly probable. Describing the Drachenhöhle, a cave in Rötelsstein Mountain, Styria, which has long been famous as a source of fossils, Professor Othenio Abel, of Vienna, writes:

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In medieval times the Drachenhöhle was already well known, and was visited by priests and nobles of the country. It was long believed to be a haunt of giants and dragons, as well as of the fabulous unicorn. Even as late as the first half of the nineteenth century the abundant remains of cave bears—supposed to be those of unicorns—were still being dug out and used for medicinal purposes.

How fossils have sometimes entered into the mythology of the American Indians is told by Professor Osborn in the preface to his "Titanotheres of Ancient Wyoming, Dakota, and Nebraska." His account is taken from a manuscript entitled "Sketches of the Life of Red Cloud," by Captain James H. Cook, of Agate, Nebraska.

It was in the autumn of 1875 . . . that I first learned of the petrified bones of strange creatures that had once occupied the lands to the eastward of the [Red Cloud] agency. Two of Red Cloud's subchiefs, American Horse and Little Wound, took me to the lodge of Afraid of Horses, where I was shown a piece of bone, perfectly petrified, containing a molar tooth three inches or more in diameter. American Horse explained that the tooth had belonged to a "Thunder Horse" that had lived "away back" and that then this creature would sometimes come down to earth in thunderstorms and chase and kill buffalo. His old people told stories of how on one occasion many, many years back, this big Thunder Horse had driven a herd of buffalo right into a camp of Lacota people during a bad thunderstorm, when these people were about to starve, and that they had killed many of these buffalo with their lances and arrows. The "Great Spirit" had sent the Thunder Horse to help them get food when it was needed most badly. This story was handed down from the time when the Indians had no horses.

In the light of present-day knowledge these and other ancient or primitive notions regarding fossils seem highly amusing. Fossils were thought by some earlier European writers to be the products of star dust; one author suggested that they might possibly have come from fish spawn that had entered chinks in the earth during the Biblical deluge; still others believed them to be the remains of creatures overwhelmed by this same flood. Fossils were also regarded as mineral concretions, or models of animals that God was later to form. It is said that one of the early Swiss naturalists suggested that

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fossil plants and animals had been placed in the rocks by the Creator to show the harmony of His work, and the agreement of the productions of the sea with those of the land; while the British geologist Geikie tells us that even within the nineteenth century a learned divine of the University of Oxford is credited with the opinion that the fossils in the rocks had been maliciously made by the Devil to deceive, mislead, and perplex mankind.

It was not until about the middle of the seventeenth century that there was any intelligent interpretation of the meaning of fossils or any clear conception of their place in nature. The credit for having been the first to recognize that marine fossils are the remains of animals and that the rocks in which these remains are found were originally layers of sediment at the bottom of the sea belongs to Nikolaus Steno (or Stensen). This able anatomist, geologist, and churchman was born at Copenhagen in 1638. Much of his life was passed in Italy, where, among other things, he studied the rocks of Tuscany and the fossils contained in them, publishing his observations in 1669. He has been called the true founder and father of geology. In the next century such men as Buffon and Guettard began to make more extensive studies of fossil remains and to compare the structure of fossils more critically with that of living animals. But it was Cuvier, about a hundred years ago, who set all this earlier work in order and thus finally established a systematic basis for the study of ancient life.

Among other pioneers of mammalian paleontology were Camper, Pallas, Blumenbach, Soemmering, Rosenmüller, and Horne. These early workers had to contend not only with superstition, prejudice, and ignorance, but sometimes even with open hostility, especially from the clergy. Moreover, they were hampered and discouraged by the difficulties presented by the imperfections of the fossils themselves. Fully realizing this, Cuvier said, according to the translation of H. F. Osborn:

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“Even if we should meet with the whole skeleton, we should have great difficulty in applying to it characteristics for the most part derived from the hair, color, and other marks which disappeared before incrustation. It is uncommonly rare to find a fossil skeleton at all perfect; the bones are isolated, confusedly intermingled, most frequently broken, and reduced to fragments; this is all our geologic layers furnish us, and is the sole source of the naturalist. . . . Frightened at these difficulties, the majority of observers have passed lightly over the fossil bones of quadrupeds, classed them very vaguely after superficial resemblances, or have not even hazarded the giving of a name to them, so that this part of fossil history, the most important and instructive of all, is of all others the least cultivated.”

This usual incompleteness of fossil skeletons and the often fragmentary condition of individual fossil bones is and always will be a serious hindrance to the fullest development of paleontology. But since the time of Cuvier the formidable nature of these difficulties has been diminished by the enormous accumulation of material gathered from almost all parts of the globe and now made available for study in the great collections of museums and universities of both the Old and New Worlds. To present-day investigators some of the earlier systematic work on fossils seems crude; but the results accomplished by the pioneers were momentous. For these able men, hampered though they were by obstacles not known to the modern student, blazed the trail and led the way into the rich field that has yielded the astonishing harvest of modern vertebrate paleontology. The works of men like Lamarck, Owen, Darwin, Huxley, Gervais, Filhol, Lemoine, Gaudry and others, who immediately followed Cuvier, are scarcely less remarkable and important than those of the true pioneers.

These earlier workers discovered not only that fossils were really remains of plants and animals, but that most of these plants and animals were, some more and others less, unlike living kinds. Also, as they studied, compared, and classified, they found that the fossils of different sorts were embedded in rocks of different layers, and that each rock layer, or formation, carried its own peculiar

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assemblage of extinct animals and plants. As knowledge increased they discovered that this fact had an unsuspected significance in the correlation of the rock formations exposed in different and often widely separated localities. This fact was seized on by the geologists, who found in it an enormous aid to the development of their subject. It was also discovered that there were definite relationships between these ancient forms of life and those living in the world today. Thus there developed the idea of succession in time of plant and animal populations and the descent of every population from an earlier one—the beginning of the present theory of evolution. Lamarck and others did much in working out these principles; but it was Darwin who first gave the facts their accepted interpretation, and for this reason it is he who has been called the founder of modern paleontology. Immediately following Darwin, and stimulated by the great impulse that he had given to mammalian paleontology, Huxley and Gaudry pushed forward its development in Europe; while only a little later Leidy, Cope, and Marsh carried on a similar work in America. The published writings of these men form the basis for investigations in every branch of vertebrate paleontology.

The history and growth of mammalian paleontology in America has been fully as remarkable as it was in the Old World. The first discovery of an American fossil seems to have taken place in Virginia. At least there is an early account in which we are told that Samuel Maverick of Massachusetts reported to the colony at Boston in 1636 that, at a place on the James River, about sixty miles above its mouth, the colonists had found shells and bones. Among these bones were those of a whale eighteen feet below the surface. It is interesting to note that this deposit of fossils continues to this day to yield extremely valuable skeletons, particularly where it is exposed along the Calvert Cliffs, on the west shore of Chesapeake Bay, in Maryland.

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From time to time after the discovery related by Maverick, an occasional bone or tooth, for the most part pertaining to an elephant or an extinct ground sloth, was found and reported in different parts of the eastern United States. A few of the specimens were sufficiently remarkable in size and form to be described, but, all combined, they were of relatively little importance. In 1792, however, Kerr, on the basis of some of these discoveries, named the American mastodon. A few years

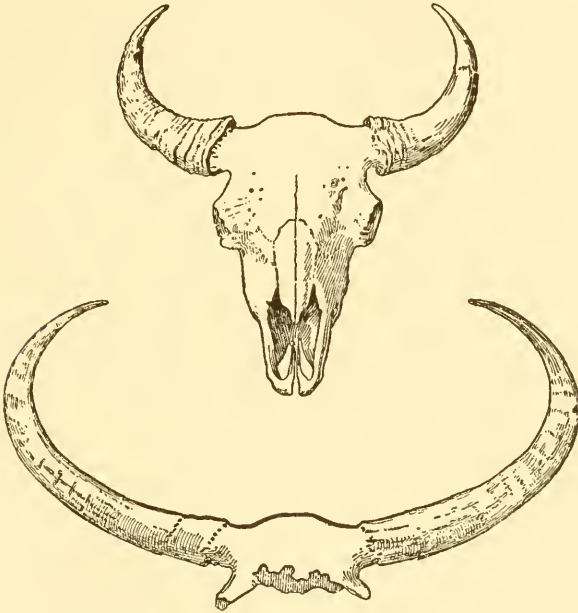


FIG. 6. Skull of the common American bison and horns of an extinct bison that lived in this country during the Pleistocene

later (1799) Thomas Jefferson published an account of some claws and bones of a ground sloth (Plate 90) found "in the western part of Virginia." He thought that they had belonged to a lion about three times as large as an

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African lion. To this creature he gave the appropriate name *Megalonyx*, meaning "great-claw"; but his mistake about the true nature of the animal was not corrected until less fragmentary specimens had been found. At about the same time Rembrandt Peale became interested in the mastodon, for which he wrongly used the name "mammoth." From the structure of the teeth he argued with much ingenuity that the mastodon must have been "an extinct immense carnivorous animal." Peale also knew of the occurrence in eastern North America of teeth like those of the true Siberian mammoth; he furthermore rightly interpreted the teeth of the great ground sloth and gave the first account of the discovery of the extinct long-horned bison (Fig. 6).

In 1823 and 1825 Richard Harlan of Philadelphia described the remains of an extinct porpoise. About ten years later he received from Louisiana some large vertebrae which he thought were parts of the skeleton of a gigantic reptile. With this idea in mind he named the animal *Basilosaurus*, the king of lizards. In 1838 Harlan obtained more bones, including parts of the skull, of the supposed reptile king, this time from Alabama. He took them to England where the anatomist Owen recognized that they had belonged not to a reptile but to a marine mammal related to the whales. Because of some peculiarities in the teeth Owen rechristened Harlan's animal *Zeuglodon*, or "yoke-tooth." This name came into general use in place of *Basilosaurus*, thus unfortunately concealing an odd bit of zoological history. A German investigator, Koch, visited Alabama in 1845 and collected many bones of *Basilosaurus*. Piecing them together somewhat fancifully he made a monstrous skeleton 114 feet long. This he exhibited on Broadway and in other places, finally taking it to Europe and selling it to the king of Prussia. It is now in Berlin, disarticulated according to its component parts.

Other men who investigated North American fossil

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mammals during the first half of the nineteenth century were Cooper, De Kay, Emmons, Gibbes, and Mitchell. Rather curiously, the extinct mammals known to these earlier paleontologists pertained either to the dawn period of the Age of Mammals or to the beginning of the epoch in which we now live. The sea-bottom deposits in which the remains of the "reptile-king" whales are found were laid down near the end of the Eocene epoch many million years ago, while the swamps in which the mastodons mired were formed on the ground left bare by the last retreating ice sheet of the Pleistocene, perhaps within a mere 50,000 years.

That the mammalian life of the vast intervening period is well represented in the rocks of many of our western States was not suspected until the great deposits of fossil bones in the Dakota Badlands were brought to the notice of zoologists. In the early pioneer days of the West, the upper Missouri or the Great Northwest country, as it was then called, was almost an unknown region. Save for the hunters, trappers, and fur traders of the Hudson Bay and other companies no white men ever visited it. To these hardy pathfinders it was known as a most inhospitable region, the abode and hunting ground of nomad tribes of unfriendly Plains Indians, but a land abounding, nevertheless, in fur-bearing animals and big game. Back in the interior of this wild country, more than three quarters of a century ago, one of these fur trappers came upon a portion of the petrified lower jaw of a strange large beast, unlike any he had ever seen. It excited his curiosity to such a degree that, on his return to St. Louis, then a frontier trading post, he carried the fossil with him. This jaw fragment thus came into the hands of Dr. Hiram A. Prout, who published a description of it in 1847. He recognized it as having belonged to a large rhinoceros-like animal as new to naturalists as it had been to the French trapper.

But the chief importance of this event lay in the fact

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that for the first time notice was given to the scientific world that there existed somewhere in the northwest country an unexplored locality where the fossil remains of unknown beasts might be found. Two years later Mr. John Evans (an assistant of Dr. David Dale Owen, who at that time was making a geological Survey of Wisconsin, Iowa, and Minnesota), inspired by the report of Dr. Prout and by the knowledge of other fossils brought in by trappers, led an expedition into this practically unexplored country and brought back with him from the Big Badlands many fossil bones representing several of the then unknown kinds of animals that had lived there in the ancient past. Evans may therefore be called the true discoverer of this noted region, and his was the first accurate description of the locality that was to become the most famous of the many collecting fields for fossil mammals on this continent. Subsequent early expeditions to the Badlands included one by Thaddeus A. Culbertson under the auspices of the Smithsonian Institution in 1850, another again by Mr. Evans in 1853, and still others by the U. S. Geological Survey, under Dr. F. V. Hayden, in 1853, 1855, and 1866. Among these exploring parties should also be mentioned those sent out by Yale University under the leadership of Prof. Othniel Charles Marsh, in the early seventies.

All these earlier expeditions were conducted under trying and almost constantly hazardous conditions, often attended with personal hardship and not infrequently at the actual risk of life; for this was before the days of the opening of the Black Hills to settlement by the white man. Moreover, the fossil field lay in the very heart of the sacred domain of the Sioux Indians, who were usually hostile to all parties that attempted to penetrate it. In addition to all this the Badlands could be reached only after long and tedious journeys by wagon or pack train. But, notwithstanding every handicap, these exploring parties made collections aggregating tons of fossil bones. The material thus secured formed the basis for the well-

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known classic works of Leidy, Cope, Marsh, and others, whose investigations, in their turn, furnished the stimulus that later sent innumerable fossil-collecting parties not only to this now famous region but to every part of the North American continent where the remains of extinct mammals could be found.

Turning now to the phase of mammalogy that concerns the study of the living kinds we find that its development has depended mainly on two factors: Interest in the problems having to do with the nature and history of the mammalian life that now exists in the world, and the finding of a technique by means of which the study could be successfully carried on. The interest was aroused by Charles Darwin and the stimulating controversies that have never ceased to grow from his writings; the technique was worked out by an associate in zoology of the National Museum, Dr. C. Hart Merriam.

The effect that Darwin's work has had on the general concept of the life of our globe is too well known to require more than brief mention here. Welding together, by the force of his genius for observation and clear reasoning, the scattered existing ideas of an evolutionary explanation of vital phenomena, he made it impossible longer to regard the different kinds of animals and plants as the fixed and rather simple elements in a finished and immutable structure. Convinced by the evidence so clearly set forth by Darwin, the naturalist of today regards all living things of the past and present as phases of one great life process whose history he is slowly learning to trace—through a period covering millions of years—and whose progress depends not on fixity and simplicity but on capacities for never-ending change and for the production of results complex beyond the possibility of realization by the untrained mind.

While the point of view from which the study of mammalogy had been regarded was thus profoundly altered by the Englishman, Darwin, the means by which

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the new approach to it could be effectually made were developed by the American, C. Hart Merriam. His interest directed by the personal influence of Baird and stimulated by the example of the brilliant contemporary development of ornithology, Merriam brought to the systematic investigation of mammals a mind endowed

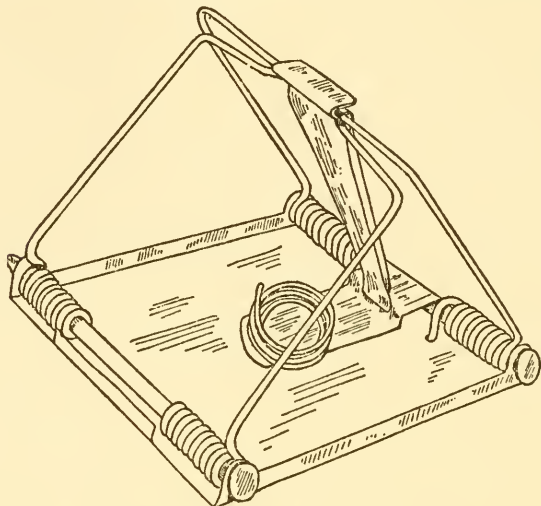


FIG. 7. Cyclone mouse trap, the implement that made modern mammalogy possible. Slightly reduced

with energy and foresight. And in his undertaking, as in so many others, success was furthered by the coincidence of two unrelated events—the awakening of his interest and the decision of a manufacturing company that had hitherto been making clothes wringers to put on the market a cheap and convenient mouse trap. The cyclone trap (Fig. 7), the first of the now familiar small traps of the deadfall type, made its appearance during the late eighties of the last century, at exactly the time when Merriam was beginning to realize that his predecessors,

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from Audubon and Bachman through Baird to Coues and Allen, had not completed the study of mammals in North America. Hitherto it had been impossible to collect small mammals systematically. With their retiring and for the most part nocturnal habits these creatures had so successfully eluded capture that the specimens on which the earlier naturalists based their studies were obtained almost by accident. Only with the advent of the cyclone trap and its successors, hundreds of which could be carried afield and set in every kind of situation, did it become possible to secure the great numbers of specimens that were needed. Armed with this effective trap, Merriam was able to apply to the investigation of mammals the principles that he had learned from the study of birds, the salient features of which are the bringing together and the minute comparative study of large series of specimens, all uniformly prepared, from every possible locality. Had this not happened at this particular time, the recent history of mammalogy would have been different throughout the world.

How impossible it was to carry on successful field work under the old conditions is well illustrated by my own experience. I began when the only traps to be had were clumsy wooden objects stained bright red and shaped like round flat cheeses, with the sides bored full of holes through which the victims were expected to thrust their heads in order to be choked. Not ineffective for catching house mice, these traps became exasperating failures when carried out to the fields and woods. A summer's industrious work with them failed to procure me a single individual of the short-tailed shrew or the red-backed mouse, two of the common mammals in the woods near my home. Then came word of the new technique and with it six dozen cyclone traps. Immediately I was able to get all the specimens that I could prepare.

In 1894 these methods were demonstrated at the British Museum, where they were adopted by Oldfield

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Thomas, the man who added more to the systematic knowledge of the mammals of the entire world than any other one investigator. They rapidly spread to Germany, France, Russia, and Japan, and they are now universally employed wherever mammals are studied.

The development of mammalogy in North America, like that of so many other branches of natural science, is heavily indebted to the explorations and surveys begun in the fifties of the last century, which preceded the laying of the first transcontinental railroads and whose main object was "to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean." The surveying parties sent out by the Federal Government were accompanied by field naturalists, who made collections surprising in extent and value, and the results of whose work were later included in the published reports of the surveys familiarly known as the "Pacific Railroad Surveys." The mammal specimens all came to the Smithsonian Institution, where Baird studied them. His conclusions appeared in 1857, under the title "Mammals," as "Volume VIII" of the above mentioned reports. This volume gave the most adequate summary of the North American fauna ever worked out by the older methods. It remained the standard authority on the subject until Merriam, thirty years later, began to revolutionize our knowledge of mammals. During the period between Baird and Merriam the Smithsonian Institution dominated the field of mammalogy in North America. Except for relatively small collections in the museums of Philadelphia and Cambridge no important mass of material for study existed outside of Washington; and at that time the Smithsonian was the only scientific agency in Washington engaged in this particular branch of research. Some well known and historically important books on North American mammals were then published, either by the Smithsonian Institution or under its inspiration; but the



Restoration of *Mylodon*, one of the giant ground sloths that lived in North America during the Pleistocene. It stood about four feet high at the shoulders and was probably too heavy to climb



American bison. The bison was the largest mammal existing in North America at the time of the arrival of the white man. Group in the National Museum

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accretion brought by them to our knowledge is insignificant as compared to that which resulted from the adoption of the new technique.

The present phase of mammalogy in North America began with the founding, in 1886, of a Division of Ornithology and Mammalogy, under the United States Department of Agriculture. This division, which subsequently grew into the Bureau of Biological Survey, was organized by Doctor Merriam and directed by him until his resignation in 1910. One of the primary objects of the Survey was to map the geographical distribution of the mammals and birds of North America, the related work on plants and insects having already been provided for. At its outset this undertaking was met by the difficulty that the kinds of mammals, when systematically collected, proved to be more numerous than had been supposed. Consequently the first step toward accurate mapping was necessarily to take a census of the mammal population and find out exactly what and how many were the kinds to be mapped. In 1885 the number was supposed to be 363; by the end of the year 1900 it had been increased to about 1,450. Subsequent counts showed 2,138 in 1911, and 2,554 in 1923.¹

¹ See "List of North American Recent Mammals 1923," by Gerrit S. Miller, Jr., issued by the Smithsonian Institution as Bull. U. S. Nat. Mus. 128, Apr. 29, 1924.

CHAPTER VI

SOME SIMPLE SHOP TALK

WHAT ARE MAMMALS?

By this time it should be clear, in a general way, that mammals are those animals whose bodies are more or less completely covered with hair and whose young are fed on milk secreted by the mother. We now wish to go into a few simple details about the structure and classification of these creatures.

A protective hair covering is characteristic of the mammal class as a whole; but this covering may be, in exceptional cases, replaced by a coat of horny scales (as in the pangolin) or by one of bony plates (as in the armadillo), or it may even be almost or entirely dispensed with (as in man, the hippopotamus, the elephant, the seacow, and the porpoise). The rule that the young must be fed on milk, however, is never deviated from, even by the mammals that lay eggs (as the duckbill and echidna) or by those that pass their lives and rear their young in the water (as the whales, porpoises, and seacows). Other characters shared by all mammals are the jointed backbone that is also found in birds, reptiles, and fishes and the warm blood that is elsewhere found in birds alone. Most mammals are four-footed, with no great differences between the fore and hind feet; but we find so many changes in the structure and appearance of the feet that some of them are at first sight quite unrecognizable as such. Some mammals possess greatly enlarged hind feet especially adapted to jumping, as the kangaroos and the

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kangaroo-rats (Plate 93); others have the fore feet turned into wings (as the bats) or into fins (as the whales, porpoises, and seacows); still others (as the lemurs and monkeys) use all the feet either as hands or feet, according to circumstances; while man alone uses the fore feet exclusively as hands. In the last point of obvious general agreement of all mammals—the position of the body—we find that the great majority of the different kinds carry themselves in a horizontal position; however, a semierect posture is assumed by the jumping mammals, as the kangaroos and jerboas, and by some of the apes; a completely erect attitude belongs to man alone; while the most amazing departures from the general rule are the head-down hanging position of the bats (see Plate 85, page 217), and the back-down climbing position of the sloths (see Plate 121, page 360).

THE DIFFERENT SORTS OF MAMMALS

Despite these six general similarities among mammals—milk food for the young, hair as the most commonly present body covering, jointed backbone, warm blood, four-footedness, and a usually horizontal position—these animals present us with a surprising variety of form. Every one knows that mammals are of different sorts, for we are all acquainted with the hoofed mammals, including the cow, horse, sheep, deer, and antelope; the flesh-eating mammals, including the cat, dog, wolf, lion, tiger, and weasel; the gnawing mammals, including the rat, mouse, beaver, and porcupine; and the trunk bearers, represented by the elephants. But are all of us aware that the soft-winged bats, which begin their pursuit of insects in the evening when the swallows abandon theirs, are mammals and not birds, or that the whales and dolphins watched from the decks of ocean steamers are mammals and not fish? Altogether there are about twenty such general sorts—technically known as orders—of living mammals, and about ten more whose repre-

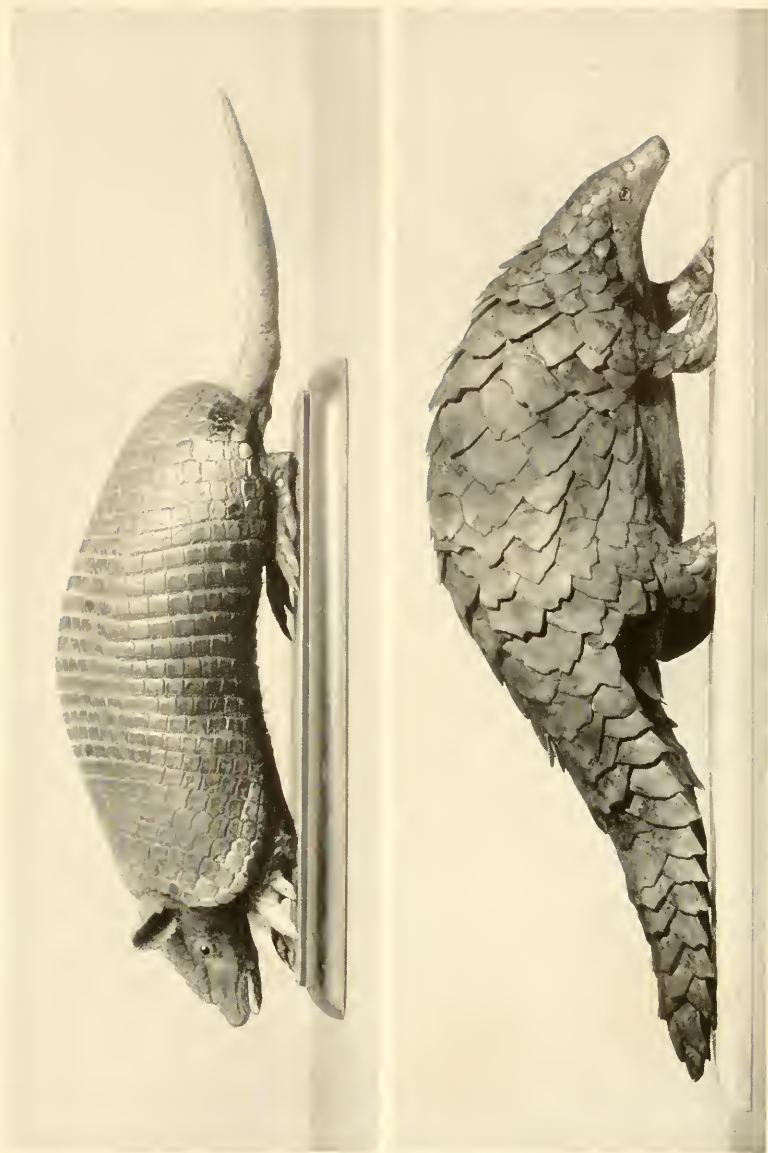
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sentatives are all dead. At first thought it might seem difficult to distinguish between so many different kinds, but such is not really the case.

To begin with, when we look at mammals as a whole so as to pick out the most fundamental of all characteristics on which to build a classification, we see that these characteristics are furnished by some easily recognized peculiarities in the process of reproduction. This process is carried on by mammals in one of three ways: First and simplest, by laying eggs as birds do; second, by giving birth to extremely small young which have been only for a very short time connected with the mother by a rudimentary internal nutrient organ, but which immediately attach themselves to her nipples, there to undergo a long course of further development, often under the protection of a special fold, pocket, or pouch of skin; third, by producing relatively well-formed and independent young which have passed a considerable period attached to the mother by a highly developed internal nutrient organ called the placenta.

The egg-laying mammals (monotremes) need not cause us any trouble, as there are only three of them—the duckbill of Australia and the two spiny anteaters or echidnas, one found in Australia, the other in New Guinea—and their appearance is so characteristic that they may be known at sight, the duckbill by the peculiarity to which it owes its name, and the echidnas by the combination of a coarsely spiny body covering and a long, tubular muzzle.

The pouched mammals (marsupials) are more numerous and more widely distributed than the egg layers, but even they are not very hard to recognize. They are found chiefly in Australia, New Guinea, and on some of the neighboring smaller islands. A few species occur in the warmer parts of America, one, our common opossum, extending its range northward to the central part of the United States. The American pouched mammals



Two armored mammals

Upper: Armadillo, distinguished by the ringlike arrangement of the plates around the middle of the body.
Lower: Pangolin, whose scales overlap each other like shingles on a roof. Specimens in the National Museum



Kangaroo rat, a desert rodent. Like some other desert mammals it is able, in digestion, to manufacture enough water from dry food to subsist without drinking. Specimen in the National Museum

SOME SIMPLE SHOP TALK

are rather uniform in appearance, all of them resembling the common opossum in a general way, though their sizes range down to that of a house mouse. The Australian members of the group, however, show great diversity in both size and structure. Among the best known of them are the kangaroos, highly modified for jumping; the wolf-like, flesh-eating thylacine; the heavily built, plant-eating wombats; the arboreal koala or native bear; and the somewhat martinlike dasyures. There are also parachuting marsupials that might be mistaken for flying squirrels and, finally, one curious, molelike, subterranean burrower. The extinct Australian pouch bearers included a heavily built plant eater as large as a rhinoceros and a creature the size of a lion with formidable shearing teeth.

By far the greater number of living mammals, including all those with which we are most familiar, are members of the third group. This group includes all the kinds that produce relatively well-developed young, born after a considerable period of prenatal growth made possible by the special internal organ of nutrition to which we have already alluded—the placenta. These mammals are the ones that have attained the greatest degrees of specialization and among which we find the greatest diversity of form. No two mammals, seemingly, could be less alike in appearance than a man and a mole, an elephant and a jerboa, or a bat and a whale, yet all of these pairs of opposites, together with creatures as contrasted in size and form as giraffes, shrews, armadillos, squirrels, lions, sloths, hippopotamuses, and gazelles, are intimately bound together by their common possession of the enormously important peculiarity that they all reproduce their kind by means of the most highly perfected device known among backboned animals.

When we come to examine more closely the mammals that make up this third great group—technically designated as the *placental mammals* from the name of the organ that is their most characteristic common posses-

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sion—we find that their secondary peculiarities divide them into twenty-six of the subgroups called *orders*, nineteen of which are represented by creatures now living, while seven are entirely extinct. Among the orders of living placental mammals nine have such easily seen peculiarities that a member of any one of them can usually be recognized at sight. These orders, each with its chief distinctive characters, are:

<i>Order</i>	<i>Distinctive characters</i>	<i>Examples</i>
Bats	True wings	
Pinnipeds (fin feet)	Mostly aquatic All 4 legs modified to serve as fins	Seal Sea-lion Walrus
Primates	True hands	Lemur Monkey Man
Even-toed ungulates	Cloven hoof on hind foot or	Cattle Deer Camel Pig
	4 small hoofs on hind foot	Hippopotamus
Odd-toed ungulates	Solid hoof on hind foot	Horse
	3 small hoofs on hind foot	Tapir Rhinoceros
Trunk bearers	Very long trunk which serves effectively as a hand	Elephant
Pangolins	Body covered with horny scales which overlie each other like tiles on a roof	

SOME SIMPLE SHOP TALK

<i>Order</i>	<i>Distinctive characters</i>	<i>Examples</i>
Seacows	Completely aquatic No hind legs Form heavy, not fishlike Nostrils in usual position	
Whales and dolphins	Completely aquatic No hind legs Form slender, definitely fishlike Nostrils (blowholes) on top of head	

Members of the other living orders, for some of which there are no English names, cannot always be so simply and certainly placed by mere inspection. Closer study is required, but not very much of it.

To begin with, there are the two very common and widespread orders known respectively as the carnivores, or flesh eaters, and the insectivores, or insect eaters. These groups are made up of animals that can usually be distinguished from each other by their size and general appearance. No one could fail to recognize at sight the striking differences that distinguish insectivores like shrews, moles, or Old World hedgehogs from carnivores like cats, dogs, hyenas, and bears.

But the problem is not always so simple. Insectivores are as a rule small, and among their number are found the most minute of known mammals—some of the shrews. Their food, as their name suggests, consists for the most part of insects; and their teeth, in conformity with this diet, are provided with fine points and low, sharp-edged ridges perfectly adapted to the work of chopping rather

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soft material. Carnivores, on the other hand, chiefly subsist on other animals, which they must attack and kill. They are necessarily larger than their prey, or at least they must be large enough to gain superiority by combining strength with agility. Among them, therefore, we find such formidable creatures as wolves and lions. Their teeth are ordinarily fitted for both the cutting of flesh and the crushing of bones, as in the dogs; but the cutting function may become the chief one, as in the cats, or bone crushing may become the most important function, as in the hyenas. Some carnivores, however, have come to subsist chiefly on fruit, and in these animals the crowns of the cheek teeth bear numerous bluntly rounded knobs instead of sharp points and cutting blades. Others again, like the weasels and some of the mongooses, are hunters of mice and small birds. Their size is so greatly reduced that some of them are not so large as a well-grown house rat, while others, such as the least weasel, scarcely exceed a fat meadow mouse in weight. Some of the mongooses strikingly resemble ground squirrels in general appearance; and likewise there are Malayan insectivores known as tree shrews which resemble the arboreal squirrels inhabiting the jungles with them. The slight external differences between these squirrel-like carnivores and insectivores give no idea of the profound structural peculiarities by which the animals are found to be distinguished when we take the trouble to examine their skulls, teeth, and soft parts.

Related to the insectivores, but bearing a deceptive resemblance to large flying squirrels, are the Malayan mammals known rather inappropriately as "flying-lemurs." They can be readily distinguished from flying squirrels, on close inspection, by the broadly rounded muzzle and by the tail, which is not bushy but is entirely enveloped in the broad membrane that serves as a parachute. From the sharp-nosed insectivores they are again distinguishable



Two species of tropical squirrels: Right, from the Malay region; left, from Central America. These squirrels represent, in brilliancy of color, the nearest approach among mammals to the parrot type among birds

SOME SIMPLE SHOP TALK

by the blunt form of the muzzle and, in addition, by the comblike structure of the front teeth.

The African and Syrian "dassies," or hyraxes, are mammals about the size of marmots and with fur not unlike that of some kinds of these familiar rodents. The teeth of the dassies however, are very different from those of the rodents. It is true that they have, like the rodents, two upper and two lower front teeth separated from the grinders by spaces; but these front teeth are not definitely chisel-like, while the grinders, small though they are, have a structure that makes them closely resemble the cheek teeth of the rhinoceroses. The dassies differ from all other mammals in having feet adapted to clinging, like a rubber sole, to the smooth surfaces of rocks and trees.

Two very important orders so greatly resemble each other in general appearance that they are not always distinguished as separate groups, even by zoologists. These are the rodents, or true gnawers, and the harelike mammals, or lagomorphs. All members of both these orders possess the one conspicuous characteristic of being gnawers, as everyone knows who has seen holes cut in walls by rats and mice or fruit trees deprived of bark in winter by rabbits. Gnawing is done by the front teeth, two in the upper jaw and two in the lower jaw, chisel-like in form and structure. These teeth grow at the base continuously throughout the animals' life, so that the wear at the cutting edge is always compensated for. The harder and softer layers of which they are composed are so arranged that the cutting edge always remains sharp as the teeth wear down. Differences in the structure of the skeleton have convinced us that the rodents are not so nearly related to the hares and their allies as the similarity of their cutting teeth would imply, but that the members of these two groups have come to resemble each other by independent development according to one plan. The plausibility of this view is heightened

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by the fact that cutting teeth working somewhat in rodent fashion have been developed by several other kinds of mammals that are admittedly unrelated to each other. Some of these are extinct, but three of them are living now: the wombats in Australia, a lemur in Madagascar, and the dassies in Africa. While there are no external peculiarities that can be depended on to distinguish every rodent from every member of the hare group, it is always easy to refer a gnawing mammal to its proper order if a skull can be examined. In the hare group there is a small cylindrical tooth behind and in contact with the main upper front cutting tooth. This small tooth is never present in any known rodent.

Finally, we come to the mammals usually known as edentates. Some of these creatures have no teeth at all, as the name *edentate* would imply; others have teeth that are simplified in structure and reduced in number. More properly, the edentates are divided into three orders: First, the Nomarthra or pangolins, which, as we have seen, can always be distinguished from other mammals by their body covering of horny, shingled scales; second, the Xenarthra; and third, the Tubulidentata.

The Xenarthra include the living American sloths, anteaters, and armadillos. Many extinct members of this order are known, some of them gigantic in size and fantastic in form.

The Tubulidentata are the aard-varks of Africa—animals strikingly unlike all other living quadrupeds—with heavy body and short legs, long, thick, muscular tail, large, erect, pointed ears, long snout, and long, protractile tongue. Their feet are provided with powerful claws for burrowing and for opening the sun-baked nests of the ants and termites (white ants) on which they feed.

THE CLASSIFICATION OF MAMMALS

So much for the different orders of mammals. We must next glance at their arrangement. For convenience in

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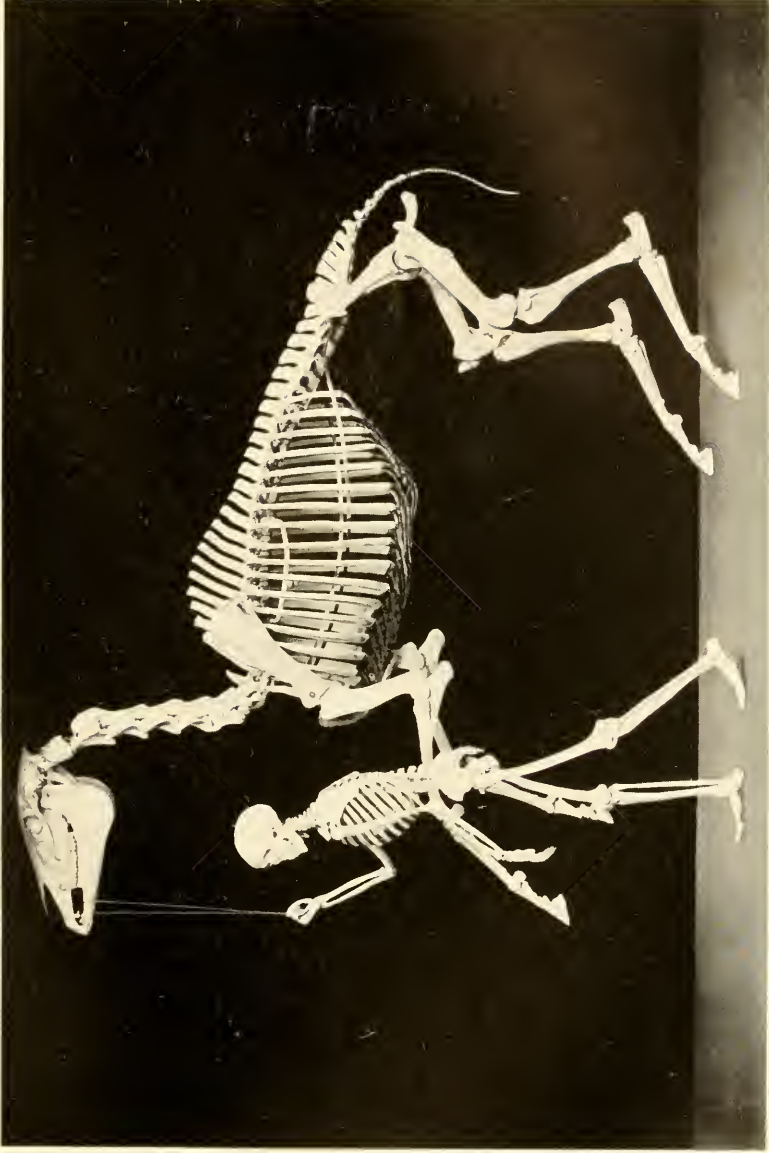
study it is necessary to classify these different orders in a series beginning somewhere and ending somewhere. Such a series might be imagined to represent in proper sequence the actual steps by which mammals have progressed from the lowest form to the highest; but this is not at all the fact. During the course of evolutionary history, mammals, like other creatures, appear to have developed along many lines radiating from a common ancestral stock, or perhaps, more exactly, from several rather nearly related ancestral stocks. The results of such a process can not be truly represented by any single line. Furthermore, the words "low" and "high," as applied to animals, have no definite meaning. They express social concepts which rest chiefly on the idea that man, as the most mentally efficient mammal, must also be the "highest," in the sense of the one that has risen most conspicuously "above" the common primitive mammalian stock. This view once conceded, the attempt used to be made to fit all mammals as nearly as possible into their proper places in a series supposed to extend from the lowly egg-laying echidna and duckbill to the supreme product of nature, man.

From the zoological standpoint, however, the efficiency attained is not the object of most interest. This is because every animal, in order to exist, must be efficient in its own particular way; and our ratings of efficiency must depend on some standard arbitrarily adopted. The factor that we can hope to determine without such appeal to preference is not the admirableness of the *results attained*, but the length of the *distance traversed* in attaining each result. In other words, the amount of change that different kinds of animals have undergone in the course of evolution can, perhaps, be objectively measured and compared, but the quality of the result certainly can not. To give a concrete example of what we mean let us take the three mammals horse, monkey, and whale. What are their relative positions in the mammalian series? Accord-

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ing to the earlier ideas, into which the concept of "quality" or "efficiency" still largely entered, the answer was: Whale, lowest; horse, intermediate; monkey, highest. Thus they are arranged in Flower and Lydekker's "An Introduction to the Study of Mammals, Living and Extinct," published in 1891. When we come to a more modern work, however, such as Cabrera's "Manual de Mastozoología," 1922, we find the order exactly reversed: Monkey, least specialized; horse, intermediate; whale most specialized. At first sight this difference may cause surprise; but the reason for it is actually not hard to find and should not be hard to understand. The earlier authors, strongly influenced by the idea of mental efficiency, declared that the primates, that is, the group that contains both man and monkey, "in any natural system must be placed at the head of the series." Near the foot, therefore, should be the position of the whales, whose structure, with its obvious features of simplification and loss of parts, precludes all possibility of the attainment of any efficiency whatever as judged by primate standards. Between these extremes of high and low efficiency stood the horse.

During the thirty years that followed the publication of "Mammals, Living and Extinct," it was realized that the primates possess many elements of structure that are little removed from those found in the insectivores, the simplest and least modified of living placental mammals. This is particularly true of their teeth, limbs, and many features of their soft anatomy. The primates have, as it were, specialized in developing hands and brains, but without greatly modifying the basic structure of their bodies. Therefore, however much we may admire the results that they have attained, we are forced to recognize that the primate stage could be reached by passing through a rather short series of changes in creatures whose general bodily structure has kept many of its primitive characteristics.



Skeletons of horse and man compared. The teeth and feet are more highly specialized in the horse; its whole weight is borne by a single toe of each foot, in contrast to the five toes and heel still employed to share the burden of man's weight. Specimens in the National Museum



Head of sperm whale. The man standing in the angle of the open jaws indicates their size. The species is distinguished by the bluntness of the snout and by the formidable teeth

SOME SIMPLE SHOP TALK

In contrast with this relatively simple general structure of the primates, we find the structure of the horse to be notably altered from the original type, especially as concerns the limbs and the teeth (Plate 95). The feet have been entirely remodeled from the old five-toed plan. The lateral toes have been done away with, through a long series of changes whose degrees may be clearly followed in the fossil record; and the median toes, shod with hoofs developed from simple claws, have become an essential part of the most highly specialized running machine that any mammal has yet been able to bring into being. At the same time horses' teeth have so increased in height that their period of usefulness has been greatly extended. Moreover, the harder and softer substances in each tooth have been so rearranged as to give rise to an efficiency in food grinding that is almost, though not quite, the nearest known approach to perfection attained by any mammalian tooth. These and other peculiarities of the horse show that the chain of his ancestors leading back to mammals of a truly primitive kind must contain many more links than the chain that connects a monkey with his past.

But, greatly though the length of the horse's ancestral line may exceed the monkey's, it is relatively short in comparison with the whale's. Consider for a moment some of the profound changes in structure that have been necessary in order to make the body of a whale swimming the sea (Plate 96) out of that of an ordinary mammal walking the earth on four legs. The contour of the whale's body must have been changed from that of a quadruped to that of a fish. The hind limbs and the pelvis must have been so entirely done away with that they exist, if at all, only as bony vestiges buried deep in the body. The anterior limbs must have been made over into flippers more perfect than those of a sea turtle. The tail must have been enormously increased in size and strength, and its extremity must have been provided with broad

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propelling blades. The bony orifices of the nostrils must have been moved from the end of the snout to a position on the top of the skull near the fore part of the braincase. The bones of the skull must have been displaced so that some of them came to override their neighbors in a manner not seen in any other mammals. To permit long immersion in water a thorough remodeling of both the structure and functioning of the breathing apparatus had to be accomplished. To conform with the new, fishlike, mode of locomotion the muscular system had to be so rearranged as to apply its main propulsive force through the tail instead of through the legs. Finally the teeth had to undergo one or the other of two very remarkable processes. They had to be changed in form so as to resemble those of no other mammals, and then either increased or reduced in number or entirely done away with. In one group of whales the teeth are replaced by totally new organs, called baleen plates, made of a horny substance that grows from the gums. The frayed-out, bristlelike edges of these plates make a strainer by means of which the animals separate from the sea water the small swimming creatures on which they feed. To produce changes in such number and of so fundamental a nature can not but require an evolutionary process vastly longer and more complicated than that needed to produce either a monkey or a horse, and it is for this reason that the whales, and not the primates, are now accorded the position representing the most extreme removal from the beginnings of mammalian life.

Applying as best we can this principle of development away from conditions of primitive structure, we have arrived at the following arrangement of the mammalian orders. Our list does not differ conspicuously from that adopted by Cabrera, which in turn rests on the one outlined by Osborn and Gregory. The extinct orders are indicated by daggers.

SOME SIMPLE SHOP TALK

<i>Orders</i>	<i>Familiar Examples</i>	<i>Orders</i>	<i>Familiar Examples</i>	<i>Orders</i>	<i>Familiar Examples</i>
Multituberculata†		Pinnipedia	Seal	Perissodactyla	Horse
Triconodonta†		Primates	Monkey	Amblypoda†	
Symmetrodonta†		Ganodonta†		Hyracoidea	Dassie
Pantotheria†		Tillodontia†		Barypoda†	
Monotremata	Duckbill	Rodentia	Rat	Proboscidea	Elephant
Marsupialia	Opossum	Lagomorpha	Hare	Sirenia	Seacow
Insectivora	Mole	Artiodactyla	Cow	Xenarthra	Armadillo
Galeoptera	Flying-lemur	Protungulata†		Nomarthra	Pangolin
Chiroptera	Bat	Notungulata†		Tubulidentata	Aard-vark
Carnivora	Dog	Pyrotheria†		Cetacea	Whale

HOW GEOLOGICAL TIME IS RECKONED

The layman who has tried to read scientific articles about fossils must have been puzzled by the unfamiliar words that are used to designate the time periods with which geologists have to deal—"Pleistocene," "Quaternary," "Paleocene," and "Jurassic" are examples—and he may have wondered what the reason is for such heated debates as the famous one in regard to whether the oldest human remains date from the Pliocene or the Pleistocene. But his trouble may be lessened if he learns that these are simply names used to denote different periods of geological history, just as the terms "Victorian," "Elizabethan," "medieval," and "ancient Egyptian" are used for different periods of human history.

The principal difficulty in explaining these geological terms to the general reader lies in the fact that the geological periods are so much longer than the historical periods with which he is acquainted. The human historical record can be traced back perhaps ten thousand years; and to most people this is as much of the past as seems important. To them Hammurabi and Tut-ankh-Amen appear to stand close to the farthest bounds of time.

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But to the geologist, whose interest lies in the history of the entire earth and all the life that has ever existed on it, the outlook is utterly different. To him Hammurabi and Tut-ankh-Amen seem so near to us as to pertain literally to the life of today; while the period with whose history he is actively occupied stretches back over years that must be reckoned not in mere thousands but in hundreds of millions.

The years and centuries of human chronology are so short that they are inadequate for the purpose of measuring the parts of a vast period like this. To try to use them for such a purpose would be as futile as to try to use microns—one of which is less than a twenty-five thousandth of an inch in length—to measure the Andes. Geologists, therefore, make no serious attempt to measure time in years any more than astronomers attempt to measure stellar space in miles. And just as astronomers express distances in terms of a process—the movement of light—so do geologists express time in terms of a process—the progression of life.

After long and patient research geologists have come to the conclusion that the structure of plant and animal forms has neither remained stationary throughout the period of life's existence on earth nor has it progressed by sudden bounds and breaks, but that it has constantly changed in a slow and orderly fashion. This process of change, continuing through millions of generations, has resulted in the gradual production of new kinds of plants and animals which, on the whole, have shown a regular tendency to be more "specialized" than their ancestors, that is to say, to be more and more advanced along the particular lines of bodily structure that are characteristic of each of the different kinds. And, in studying the fossils embedded in rock deposits, geologists have found that the plant and animal life represented by these fossils had reached some definite stage in the process of specialization at the time when each deposit was made.

SOME SIMPLE SHOP TALK

It often happens that two deposits lying in contact with each other contain fossils that pertain to different stages of specialization. This is regarded as evidence that the rocks in question were formed at different periods of time. Again rocks on opposite sides of the world may contain fossils so much alike as to show that they are of about the same age.

By comparing the fossils found in the rock deposits of every part of the world geologists have gradually worked out a chronology expressed in terms of the specialization of plants and animals. This is a perfectly familiar way of reckoning. We often speak of the Renaissance as following the Middle Ages without thinking of exact dates in years; nevertheless we have no difficulty in understanding that these words designate two successive stages in the development of European civilization. So it is when geologists speak of the Pliocene as following the Miocene: these terms designate two successive stages in the development of living things. And however impossible it may be to give them limits in years, all the stages named by geologists form so many chapters in the history of the earth.

The study of geology was begun in western Europe, a region where the great groups of sedimentary rocks are easily distinguished from each other both because of the characteristic features of the rock units that make up each system and because each group is marked off from those lying below and above by definite lines or planes known as unconformities. The fossils embedded in the rocks of each group are so obviously different from those in both the underlying and overlying groups that they give the impression of abrupt changes in animal life. Misled by such conditions and working at a time when the earth was generally supposed to be only a few thousand years old, the early geologists concluded that each group of rocks represented a long period of tranquillity and that the unconformities between the sedimentary groups

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represented great cataclysms which from time to time destroyed all life and profoundly changed the order of things earthly. The restoration of life after each cataclysm was supposed to have necessitated an entirely new creation. On the basis of this erroneous conception geological time was at first divided into four major periods which were given the names Primary, Secondary, Tertiary, and Quaternary.

But increased knowledge, coming from the extension of the study of geology to other parts of the world, later proved that this doctrine of "cataclysm," which for a time had a wide following, was not supported by the observed facts. More extended work showed that the geological records missing in Europe had been preserved, in part at least, in the rocks of other continents and that the supposed cataclysms, if there ever had been any, were not widespread but were at most decidedly local affairs. Thus geologists gradually came to recognize that the process of world building must have been continuous and orderly and not disjointed and capricious. This newer conception created the necessity of an elaborate system of names, each with a definite meaning and representing a definite time period, by which the student of geology could designate and give relative values to events in the geologic time scale. Such a system has been devised and is now in general use. Since most of its terms are not translatable into our common vernacular, and since it will be necessary to use some of them in our story, an outline of the system is here given for the benefit of our readers. It is to be read from the bottom, representing the most ancient time period of which we have any record in the earth's crust, upward to the "Recent," a term used to designate the time during which the animals and plants have been essentially as they are today.

In most works on geology the Recent and Pleistocene are treated as forming a special period known as the Quaternary and characterized chiefly by the presence of

SOME SIMPLE SHOP TALK

man. As this appears to us an arbitrary and unnatural procedure we prefer to join the Quaternary with the Tertiary, as its general fauna indicates it should be, and let the name Quaternary disappear. Even more arbitrary, in our opinion, is the not infrequent practice of making the Quaternary period equivalent to a sixth great era called the "Psychozoic," simply because in it alone do we find undisputed evidence of the human mind. And finally it should be pointed out that there is no clear distinction between the Pleistocene and the Recent epochs. Few if any new types of mammals can be shown to have arisen since the Pliocene; but throughout this time there has been a general dying out of mammals, especially of the larger, more specialized kinds. What geologists call, for convenience, the "Recent" epoch is merely the present stage of this process, corresponding roughly to the time since the last glacial retreat.

THE CLASSIFICATION OF GEOLOGICAL TIME		
<i>Era</i>	<i>Period</i>	<i>Epoch</i>
Cenozoic (Age of Mammals)	Tertiary	Recent Pleistocene Pliocene Miocene Oligocene Eocene Paleocene
Mesozoic (Age of Reptiles)	Cretaceous Jurassic Triassic	
Paleozoic (Age of Ancient Life)	Carboniferous Devonian Silurian Ordovician Cambrian	
Eozoic (Age of Dawn Life)	Algonkian	
Azoic (Age of No Life)	Archean	

CHAPTER VII

MUSEUM COMEDY

THE routine of museum work is often lightened by bits of comedy, enacted by the public itself, a few of which are worth putting on record.

While the skeleton of the blue whale in the National Museum was being bolted together for exhibition a visitor approached the expert who was directing the work, and, pointing to the whale's shoulder blade, said, "I am an old whaler and I have probably cut up a great many more whales than you ever saw; and I want to tell you that you are making a very bad mistake. That bone goes at the end of the tail and not on the ribs where you are putting it. You ought to take it off before any one else who knows has a chance to see it." This strange belief about the anatomy of whales appears to be widespread. I met with it very unexpectedly in a whaler who used to live in Provincetown, Mass., a man unusually well informed about the creatures he had seen on land and at sea. Walking among the sand dunes near the town we came to one that the wind was hollowing out, gradually uncovering the skeleton of a large whale, parts of which were scattered about. We began to gather together the bones. I soon found a shoulder blade, but on naming it I was immediately told that I was wrong. "That is the fluke bone," said my whaler, "it goes at the end of the tail." No argument that I could bring forward had any effect. In reply to everything I could say, I was told: "The flukes need something to hold them out flat, and what other bone is there that can do it? Besides, if this

MUSEUM COMEDY

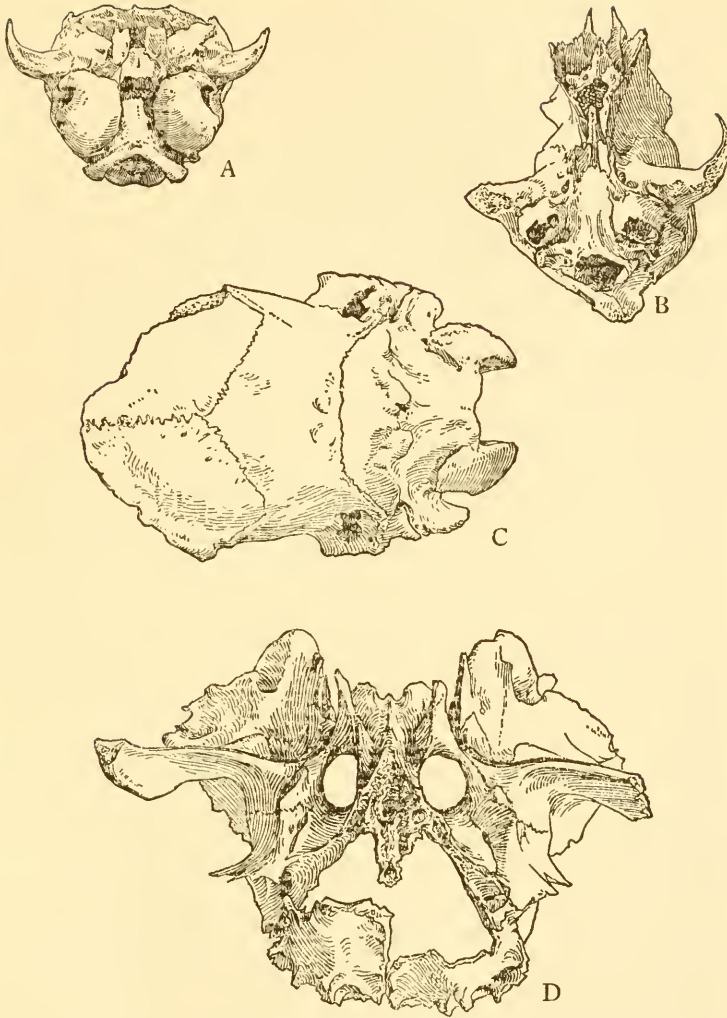


FIG. 8. Skull fragments difficult to identify: A, broken skull of a cat; B, broken skull of a dog; C, broken skull of a sheep; D, piece of the under side of a cow's braincase, supposed by its finder to be the skull of a strange animal with two small eyes and a large, one-sided mouth

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was a shoulder blade there would be another, *and you'll not find another.*" And so it turned out to be. We searched for an hour, using pieces of ribs to probe the soft white sand; but no mate to the broad, flat bone could be found, and the case went hopelessly against me.

Strange though it may seem, a month rarely passes at the National Museum without the receipt of bones or teeth of horses, cows, sheep, pigs, dogs, or cats, sent in by their finders as puzzles that have baffled the combined knowledge of some entire rural community. And this inability to recognize disconnected parts of the skeletons of common domestic animals is not confined to the unlettered. Not long ago one of the most characteristic and easily recognized bones of a lamb's foot was thus sent to us for identification by a teacher of animal husbandry in a fairly large college; and we were once greatly surprised at receiving from a field naturalist of wide experience a broken dog skull that he had identified as the skull of an embryonic seacow.

Usually the package contains objects like those in Figure 8, and the letter accompanying it runs somewhat as follows: "I am sending you the skull of an unknown animal plowed up on a farm near here. No one in this community can tell what it is and so I am asking you. What we do not understand is the eye. It has only one eye and that is in the middle of the forehead; also it has horns growing out under the eye and no teeth. Please tell me what this bone is and what it is worth."

Such a letter can be answered almost without looking at the specimen. The skull in the dog, cat, horse, cow, and sheep—though not in the pig—has a region of mechanical weakness between and behind the eye sockets. At this weak part the front section, including the muzzle, palate, and teeth, is readily broken away from a weathered skull when struck by a plow or shovel, run over by a cart wheel, or washed about in a stony stream bed. After such an accident the round, toothless braincase bears a

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vague resemblance to a human skull; and to an unpracticed eye it carries no suggestion of incompleteness. Small wonder, therefore, that it is not recognized as part of a familiar domestic animal. This breaking away of the fore part of the skull always exposes one or more orifices leading into the brain cavity at or near the middle line. When there is only one of these holes it is mistaken for a single eye; when there are two they are imagined to be a pair of eyes looking directly forward. The broken-off stubs of the cheek bones form the supposed horns. The absence of teeth is due, of course, to the fact that the teeth have all been carried away with the missing muzzle.

Teeth of supposedly strange animals are often sent to the Smithsonian Institution by their finders. At first it seems astonishing that so many people who have handled cattle, horses, and pigs all their lives should have no idea of the appearance of an isolated tooth of any of these animals. But the fact is that the view of the teeth obtained by opening the mouth of a living cow or horse or by looking at the head of a freshly killed animal gives no idea of the depth to which the teeth penetrate into the bones of the jaws. Pigs' teeth, which can be better understood from a surface view, are less often sent to us, though one came in not long ago from a professor of veterinary medicine who did not know what it was.

The information, conveyed to the finders, that these objects, which have excited so much local interest, are nothing more than parts of common domestic animals is not always welcome, as the next incident will show.

Many years ago a hotel proprietor in one of the Central States addressed to the National Museum the photograph of something that he had found among drift on a river bank while fishing. He wrote as follows:

The skeleton is a remarkable curiosity. Length 19 inches circumference $7\frac{1}{2}$ inches Length of tail 3 inches $1\frac{1}{4}$ inches wide $\frac{1}{4}$ inch thick end of tail square. Vertebrae six in No. circumference $5\frac{3}{4}$

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inches held together by dried flesh on back and ligaments between the bones. No spinal marrow. Thin covering of head $1\frac{1}{2}$ diameter. No bones. Neck Cartilago. I have shown the skeleton to hundreds of Traveling Men from all over the U. S. Not one has ever seen anything like it. Will you do me the kindness to write me and tell me what it is—from appearance of articulation it either had a No of legs or ribs. The reason I did not send the skeleton was I feared that you might not think it necessary to return it. . . .

The photograph failed to reach its destination, and, on being informed of this loss the owner of the skeleton intrusted the actual specimen to the mails. At this time he wrote:

I today send you by mail a Reg. Pkg. containing the skeleton that I wrote you sometime ago—it is certainly a remarkable Curiosity, as I have shown it to more than five hundred traveling men—who had been all over the U. S. & who was unable to class it. It is the skeleton of an aquatic animal—it is the only animal skeleton I ever saw without a spinal column. Please give me the name of the animal if you can. If you desire to purchase it—write me what you are willing to pay for it. If you dont want it do me the kindness to return same.

The strange object fared better than the photograph and arrived safely at the museum. Here it was recognized as the breastbone of a horse, cut or broken free from the ribs. A report to this effect was officially made, and the subject, which, to us, appeared to be nothing more than a matter of ordinary routine, had been almost forgotten, when the Secretary of the Smithsonian Institution received the following estimate of the abilities of his scientific staff:

I acknowledge return of skeleton—but cannot sign receipt sent as the breast bone of a horse. The reason I sent the skeleton to you was that I believed that employes were fully competent to discharge their duties. I would suggest that you pump the whisky out of the man who made that report and send him to the lunatic asylum or Keely Institute. I am an old retired Physician. I can give the name of every bone in a horse or man. Have always taken an interest in the study of Natural history. I have shown the skeleton to over five hundred traveling men, who never had seen anything like it. Until my Drug House was destroyed by fire I had the largest collection of rare curiosities in this County. I desire to state to you that I am satisfied the



Polar bear and cubs with a dead seal. Group in the National Museum



Coyotes, or prairie wolves, representatives of the dog family. Group in the National Museum

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skeleton was a See Animal & came up the Mississippi River from the Gulf of Mexico. It was an aqutical animal & died from the effect of fresh water. I shall send the President a Photograph of the Animal when he returns with a copy of the letter sent me. I shall also send to many prominent relatives & personal friends in your city. I do not censure you for its classification but your man as his opinion is not only absurd, but repugnant to common sense itself. You may say to your man that I will wager him one thousand dollars to One hundred that the skeleton is not the breast bone of a horse.

As a variant from the monotony of naming parts of domestic animals we once received some shreds of a substance declared by the sender to be parts of a large piece of dried mastodon meat found near the banks of the Yukon River. This material was examined with considerable interest in the hope that it might be the flesh of a buried elephant similar to the frozen mammoths that have been discovered in Siberia. Disappointment was the only result, as the mineral nature of the fibers was immediately recognized. The specimens were therefore turned over to the geologists, through whom a report was made. No reply was received from the owner, and the subject passed out of mind. Fifteen years later I visited the Yukon, and on arrival at one of the larger towns, I saw, displayed in the windows of several "curio shops," bits of asbestos labeled "Fossil Mastodon Meat." At once I recollected the incident in my office at Washington, and determined to find out whether the owner of the "mastodon meat" and the sender of the specimen for identification might be one and the same person. I had no difficulty in tracing him to his loft, where he made cribbage boards from slabs of fossil elephant ivory and cut napkin rings from sections of the horn sheaths of the extinct long-horned bisons (see Fig. 6, page 233), whose skulls are often washed out during placer-mining operations in the gold-bearing gravels. Finding that I was interested in bones he soon brought up the subject of mastodon meat, and told me the story of his unhappy experiences with persons who

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might have been expected to be less ignorant than the facts showed that they were.

In the first place he assured me that there could be no doubt that the substance shown in the shop windows was dried mastodon meat. He had found it himself, and a large tusk was lying beside it. That ought to prove to any one that it was part of a mastodon. Then as to its being meat, he had given a piece to a neighbor, who gave some of it to a cat, and the cat had eaten it! There could be no doubt; but just to make sure he had sent a piece to the Smithsonian Institute where they are supposed to know about such things. And what do you think they told him? They had sent back word it was nothing but asbestos. They didn't know as much as the cat. After this he ought to have known better, but somebody told him about a college in Ohio where he could find out exactly. He sent a piece there, and they didn't have any more sense than the ones in Washington. Told him the same thing—*asbestos*. He wished he could see some of those fellows near to and tell them just what he thought of them. *Asbestos!*

While he was talking I had seen some foot bones of a fossil sheep lying among the litter on his table. The more I looked at them the more interested I became. I must have them; but a wrong word would be fatal.

As he finished I said: "You're right, those people down there don't know everything. But tell me about those little bones on your table." He picked them up and said: "They came from the Great Bonanza placer mine. I never saw any others of that kind, and I don't know what they are, but they're too small to make anything out of. I've seen you looking at them and I reckon you'd like to have them. You seem to understand some things, and I've had fun telling you about those fool people. Take them along."

CHAPTER VIII

THE MOST ANCIENT KNOWN MAMMALS

THE Age of Mammals owes its name to the fact that it is the time period during which the mammals have been the most conspicuous type of vertebrate life. Throughout this period the warm-blooded, milk-giving vertebrates have been the ones that have most successfully carried on the two great functions of the animal world—the turning of vegetable substances into animal bodies and the turning of these bodies again into others; for it is thus that animal life continues through the generations. Vegetable eaters must forever consume plants, and flesh eaters must forever consume animals, otherwise the chain of living beings would break.

Before the Age of Mammals, and through a much longer period of time, the cold-blooded, egg-laying reptiles occupied the position in the animal world now held by the mammals. They dominated the vertebrate life of their time, and among them, as later among the mammals, there arose a multiplicity of plant-eating and flesh-eating kinds, each fitted to take advantage of some particular opportunity to live offered by land or sea.

During many millions of the years when reptilian life dominated the earth, however, some very peculiar types of small mammals were leading an inconspicuous existence. Undoubtedly there were many such types, but only four of them have yet been discovered. By different writers it has been believed that these very ancient mammals were ancestors of either the egg layers, the pouch bearers, the rodents, or the placentals in general.

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But according to several authorities, including the latest, Dr. George G. Simpson, no direct descendants of any of the known reptilian-age mammals are living today. Doctor Simpson believes, however, that early and as yet undiscovered members of one group of them, called the Pantotheria, may have been ancestral to our present-day pouch bearers and ordinary mammals. The lines as revealed by actual fossils have long been extinct; and only one of them, the "Multituberculata," was able to reach the dawn period of the Age of Mammals. But this one, apparently the most successful of the ancient lines, had an astoundingly long life. Its fossil record shows that it existed through a period not less than twice as long and perhaps four times as long as the entire subsequent mammalian age.

These very ancient mammals are mostly known from imperfect fossils, in many instances merely from tiny isolated teeth, found in rocks at widely separated localities in Europe, Mongolia, South Africa, and North America. They have been studied by comparatively few paleontologists, and they are wholly unknown to the general public. Naturally, therefore, they have no common names. Doctor Simpson has recently published two beautifully illustrated volumes in which he fully describes all these "Mesozoic" mammals, as they are generally called. He arranges the different kinds in four orders, called the "Multituberculata," the "Triconodonta," the "Symmetrodonta," and the "Pantotheria." They are distinguished from each other principally by differences in the structure of their teeth.

Inconspicuous and seemingly unimportant though the "Mesozoic" mammals may seem they are peculiarly interesting because of the vast time-period during which they existed, and because certain features of their anatomical structure seem to indicate the path that mammals may have followed in developing away from reptiles.

CHAPTER IX

EGG-LAYING MAMMALS

STRANGE to say, there are three mammals that lay eggs and brood them after the manner of birds; one is about the size of our muskrat, the other two are often considerably larger. All three, their young once hatched, feed the nestlings on milk which exudes through minute pores in the skin of the mother's abdomen. One of these egg layers is water-loving, soft-furred, and duck-billed (Plate 100). It has two names, duckbill and platypus. The two other egg layers live entirely on land. Unlike the furry duckbill they are quill-covered, slender-snouted, and ant-eating (Plate 99). They are often known as porcupines, or more correctly as spiny anteaters, or echidnas. At present the duckbill is found in Australia and Tasmania only; one of the echidnas in Australia, Tasmania, and New Guinea, and the other in New Guinea only. Certain fossil mammals, some of them very ancient, have been thought by different writers to show that the egg layers were once distributed over much of the world, but this idea is utterly rejected by the most recent investigator, Dr. George G. Simpson, who declares that nothing whatever of the group's history is known from specimens older than the Pleistocene or outside the region where egg layers now live.

The egg-laying habit does not point, as might at first seem likely, to any near relationship with the birds. It indicates, rather, a hold-over from some far away reptilian ancestry; and in support of this idea we find that the eggshells of the egg-laying mammals are soft and

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leathery like those of some reptiles, not hard and brittle like those of all birds. The eggs of both the duckbill and the echidnas are slightly more than half an inch long and whitish in color. The Australian echidna lays only one egg at a time. The duckbill lays two or sometimes three eggs, whose sticky shells hold them together in a very unusual position; instead of being strung end to end they adhere by their sides (Plate 100).

Little or nothing is known concerning the habits of the New Guinea echidna. The animal differs from its Australian relative in having a more slender and decidedly down-curved muzzle or beak. Presumably its ways are like those of the more familiar animal, about which Dr. Frederic Wood-Jones writes:

The *Echidna* is an animal which is extremely difficult to observe in its natural state, and accounts of its habits have, for the most part, to be taken from observations made upon captive animals. It is crepuscular or nocturnal in its activities, and obscure in all its ways of life. . . .

The animal is a burrower of the most remarkable kind, and its powers of clinging to, and sinking into the earth, can hardly be appreciated by those who have not witnessed the process. If an *Echidna* be placed upon a hard surface into which it is unable to burrow, it is capable of making off at a good pace; but the moment that it encounters ground into which it can dig, it ceases all attempts to escape by shuffling along, and proceeds at once to sink directly downwards into the earth. In this process it does not burrow in head first, as do most burrowing animals; but it sinks in, in a way that can only be described as all-over-at-once. If it be interfered with in the preliminary stages of this process of digging itself in, it will be found that the animal appears to be miraculously stuck to the ground; and, once it has started to descend, it is almost impossible to arrest its progress and draw it back.

Some idea of the strength of the animal may be gained from the experience of an Adelaide zoologist who put an *Echidna* in his kitchen for the night. Next morning all the furniture—the heavy dresser, the table, chairs, boxes, etc.—was found moved from the walls towards the middle of the room. The gas stove, which was fixed by its pipe, alone withstood the animal's efforts at removal.

In finding its way about, the sensitive snout obviously plays an important part, and everything is tested by being probed with the tapering end of the muzzle. In this testing it is not only the sensitive skin which is called into play, for, judging by the frequent inspiratory sniffs which

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form the accompaniment of most of its activities, the sense of smell is an important guiding factor.

Its vision does not appear to be at all acute; and its range is apparently restricted to comparatively near objects. The sense of hearing, on the other hand, is evidently well developed, and the animal has an altogether extraordinary power of appreciating, either by auditory impressions or by a tactile sense of vibrations, the advent of an approaching footfall.

Its only vocal accomplishment appears to consist in varying modulations, and amplifications, of the sniff through its nostrils.

Although the *Echidna* is often assumed to be solely a destroyer of "white ants" or termites, and is commonly depicted in the act of tearing into a termites' mound, it is, in South Australia at least, an animal which devours a variety of small insects.

In confinement *Echidna* will drink milk in most remarkable quantities. It will also eat bread and milk, finely chopped hard-boiled egg, or indeed any food substance which can be reduced to a suitable consistency. The gape of the jaws is so small that the mouth opens no further than to permit the long tongue being protruded and retracted at a rapid rate. Any animal substance which can adhere to the tongue, and be withdrawn with it into the mouth, appears to be appreciated by the "Porcupine," but it has a special liking for a raw egg with a hole made in it to admit the tongue.

Its power of recovering from severe wounds; its tenacity of life; and its extremely slow death, even when mortally stricken, are all reminiscent of the lower Vertebrates. . . . At the present time the "Porcupine" is in no immediate danger of extermination. Fortunately for itself it is of no commercial value. It has no useful, or ornamental skin to attract the trapper, and since it has ceased to be a desirable article of diet for the aboriginal it is in the happy position of being practically useless to man. It does not in any way actively harm any human enterprise, and so it does not fall under the ban of the exterminator. Again, it has two other great assets—it is not attracted by the poison bait, and it is nearly fox-proof. Only the rabbit and the rabbit trapper are capable of appreciably interfering with the continuity of its archaic story. The burrowing rabbit, in all places in which it is abundant, causes a house shortage for other burrowers. The competition for breeding burrows is a very real factor, and it enters into the lives of some of the Marsupials even more acutely than it does in the case of *Echidna*. Again, the steel trap, intended for the rabbit, will often catch the unsuspecting Ant-eater. It is so obscure in its ways that its presence is not always suspected, and, although nowhere existing in great numbers, it retains a tenacious hold on a very wide area of country, in which, it is hoped, it will long remain unmolested.

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The other egg layer, the duckbill, is unquestionably one of the most remarkable of living mammals. Until a few years ago its habits and life history were very imperfectly known, and accounts of it in the general literature of natural history consisted largely of guesses and conjectures. Recently the duckbill has been made the subject of an elaborate and very interesting book, written by the Australian naturalist Harry Burrell as the result of many years of active field work and careful study of the animal at large and in captivity. From this volume we have prepared the following account of the creature, freely paraphrasing the author's words.

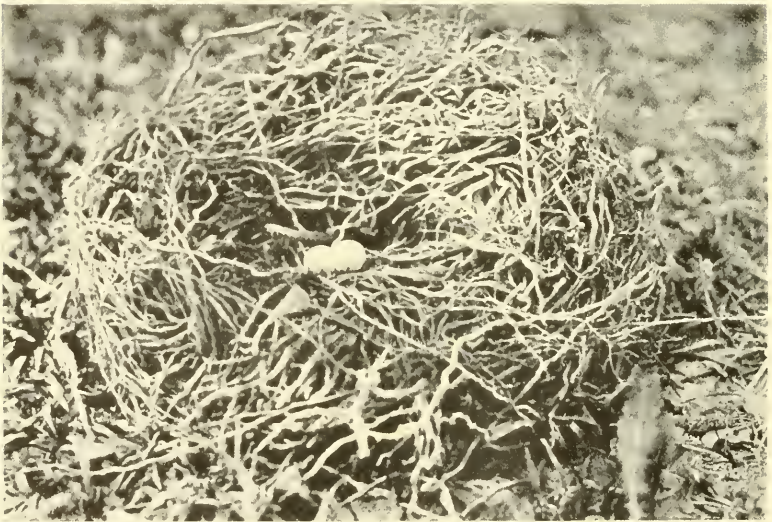
The discovery of the duckbill at the end of the eighteenth century and the printed description of the first specimen received at the British Museum (1798) at once launched controversies about the animal's structure and habits, some of which are not yet entirely set at rest. At first naturalists even suspected another imposture like that of the "eastern mermaid," which the artful Chinese had foisted upon credulous European adventurers and which consisted of the skin of the fore part of a monkey skillfully sewn to the tail part of a fish. Such suspicions were, however, immediately dispelled by an appeal to anatomy.

But the troubles of zoologists did not end with proof of the reality of the duck-billed creature. As Burrell says, "A furred animal should obviously be a mammal—that is to say, it should have a uterus to contain its foetal young, and milk-glands with external nipples for the suckling of the young when born. But Home (1802) found no uterus, no mammary glands, and no nipples. Was the platypus a mammal?"

Another controversy concerned the method of reproduction. Did the platypus really lay eggs as reported? And, finally, a third debatable point, "which can scarcely be said to have been settled even yet, has been concerned with the spur which is found upon the hind-limb of the male. Numerous writers have quoted cases of severe



The Australian echidna, an egg-laying mammal. It has a long, extensible tongue for licking up ants



An egg-laying mammal and nest

Upper: Duckbill, or platypus. When walking the animal holds the toes of the forefeet doubled under to protect the swimming membrane.

Lower: Nest of duckbill and pair of eggs joined in the usual way.

From Burrell's *The Platypus*

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wounds, while others, including Dr. George Bennett, who handled large numbers of male platypus, never knew the animal to attempt the use of its spurs for offensive purposes."

Concerning the interesting question of the mammary glands of duckbills, Mr. Burrell tells us:

The mammary glands differ from those of mammals in general, and may be considered as modified sweat-glands. They open by a number of pores upon a small area of skin, there being no teats. After the end of the breeding season they become so small as to be easily overlooked, and will apparently yield no milk at the time when the young are just hatched from the egg. In these respects they differ very markedly from the milk-glands of ordinary mammals, and have afforded grounds for further lively arguments.

Coming next to the animal's form and appearance, Mr. Burrell writes:

The most conspicuous feature about the bodily form of the platypus is its prevailing flatness. The naked muzzle is broad and flat; the head is so much depressed that the eyes have become more dorsal than lateral in position; the trunk is broad and flat, though in profile its outline rises from the shoulders to a point a little behind the middle of its length, and then falls towards the tail; a cross-section has the form of a low arch, a good deal more broad than high; finally, the tail is broad and flat, with a broadly rounded tip.

The skin, kimono-like, is over-large for the size of the body, and, except at all the animal's extremities, it appears to be entirely dissociated from the primary nervous system. That is to say, a platypus will readily respond to the slightest touch on either feet, paws, bill, lips, or tail, but will not shrink from being soothingly stroked, from forehead to rump, along the fur. This characteristic is most apparent while the animal is submerged in water, where it is unable to see, hear, or smell the experimentalist. . . .

The muzzle, which shows some resemblance to a duck's bill in the dry condition, is very different in the living animal. The naked skin is thick, but soft, moist, and flexible, very unlike the horny beak of a bird. On the upper surface it is slate-coloured; on the under, of a yellowish flesh-colour, often broadly mottled with greenish slate. From the base of each mandible a cuticular flap projects backwards over the fur of forehead and throat.

The muzzle, with its flaps, is a highly specialized sense-organ. The whole of its exposed surface, both above and below, is pitted with

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minute pores, which extend on to the cuticular flaps and mark the sites of the highly specialized touch-corpuscles. When under water, the animal depends principally on its delicate sense of touch for finding its way about, and it is fairly certain that the same condition obtains in the burrow. . . .

A somewhat remarkable transformation of the fore-claws is essential before a young platypus can fend for itself. In the nestling stage, the slender claws curve downwards and are grooved beneath. The reason for this curvature is, apparently, to give the nestlings a firm grip of the mother's abdominal fur when vigorously nuzzling to induce a free flow of milk. As the nestling grows, the claws gradually become straighter and broader, and instead of remaining grooved, the nails become slightly convex below. By this time the paw is adequately webbed for swimming, and consequently the young one is free to forage alone. . . .

The contorting ability of an adult platypus is quite remarkable. It can extend its length six inches without raising its abdomen from the ground. . . . When lying fully extended on its back, the platypus can, by placing the lower portion of its bill on its breast, and without raising its head to any appreciable extent, double itself ventrally until its head passes its tail, and that pliable member is itself doubled until the creature becomes normally righted on all fours, dragging its tail behind it. This act it can accomplish in a tunnel equal in circumference to the performer so doubled. . . .

In both platypus and echidna there occurs on the inner side of each hind-limb of the male a movable spur. This is found in the young female also; but in the full-grown female it has disappeared, leaving a depression to mark the spot where it had been. This condition suggests that the spur and depression are of the nature of secondary sexual characters, and have something to do with reproduction. Such was the general belief for twenty years after the first discovery of the platypus. Then it was reported from Australia that the spur of the male was capable of causing serious wounds, followed by dangerous symptoms due to a venom expressed through the spur. . . .

In March 1817 extracts from a letter from Sir John Jamison, dated at Regentville, New South Wales, September 10, 1816, were read before the Linnean Society of London. . . . Jamison writes: "I cannot avoid relating to you an extraordinary peculiarity which I have lately discovered in the *Ornithorhynchus paradoxus*. The male of this wonderful animal is provided with spurs on the hind feet or legs, like a cock. The spur is situated over a cyst of venomous fluid, and has a tube or cannula up its centre, through which the animal can, like a serpent, force the poison when it inflicts its wound. I wounded one with small shot; and on my overseer's taking it out of the water, it

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stuck its spurs into the palm and back of his right hand with such force, and retained them in with such strength, that they could not be withdrawn until it was killed. The hand instantly swelled to a prodigious bulk; and the inflammation having rapidly extended to his shoulder, he was in a few minutes threatened with lock-jaw, and exhibited all the symptoms of a person bitten by a venomous snake. The pain from the first was insupportable, and cold sweats and sickness of the stomach took place so alarmingly, that I found it necessary, besides the external application of oil and vinegar, to administer large quantities of the volatile alkali with opium, which I really think preserved his life. He was obliged to keep his bed for several days, and did not recover the perfect use of his hand for nine weeks. This unexpected and extraordinary occurrence induced me to examine the spur of the animal; and on pressing it down on the leg the fluid squirted through the tube; but for what purpose Nature has so armed these animals is as yet unknown to me."

No other mammals, except the echidnas, are known to possess poison glands and sharp-pointed spurs functioning like the glands and fangs of venomous snakes. Such extraordinary weapons have naturally excited much curiosity, because all other mammals are able to live without them and there is nothing in the known economy of the egg layers to suggest that these creatures have special needs with which poison spurs alone can cope. Duckbills and echidnas alike are practically without natural enemies, and there is no reason to suppose that they are unusually quarrelsome among themselves. Why, then, should they be so formidably armed? Strange to say, this question is as far from a satisfactory answer now as it was when Sir John Jamison wrote more than a century ago. Mr. Burrell, however, has the following personal experience to relate:

After placing the robust male platypus on a table, abdomen uppermost and tail towards me, with my bare hand I held the wriggling creature by the head. Then, to exasperate him, I placed my right arm on his tail and deliberately tantalized him by tickling him from back legs to brisket with my fingers. Several times he raised his spurs simultaneously as if sparring for a grip, but each time lowered them again. Tiring of such monotonous behaviour, I removed my arm to rearrange his position and to reverse my hand-holds temporarily.

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But, while I was bringing my bare hand back to grasp his tail, the platypus, as though aware that I was off my guard, like a flash struck with his spur and ripped the edge of my left hand for a distance of over an inch towards the little finger. This action was so quick and unexpected that it certainly gave me a shock. After placing the platypus back in the box, I repeatedly squeezed the wound and made it bleed very freely.

My wife then took a hand, and flooded the wound with iodine twice within half an hour; each time she did so, the pain was acute in the extreme—far more so than when first inflicted. The rip, which was jagged by my tearing away from the temporarily rigid spur, was $1\frac{1}{8}$ inch in length, and $\frac{1}{8}$ inch in depth. Now, whether the pulling away of my hand simultaneously with the striking of the spur saved me from receiving a full dose of dope, or any at all, is questionable. But two or three days later, when I had almost forgotten the event, I felt a slight pain under the arm, and noticed a redness leading thereto from the wound.

As a shelter in which to build her nest, lay her eggs, and care for her young until they are able to enter the water in search of food, the female duckbill constructs a burrow that penetrates the river bank from near the water's edge to a length of from five to upwards of sixty feet. About fifteen or twenty feet seems to be the usual length of a nesting burrow. The unusual way in which these burrows are made is thus described by Mr. Burrell:

A remarkable feature of the burrow is that no soil is ejected, but the whole of it is reduced to a consistency suitable for packing into the sides of the burrow, and even the soil dislodged when commencing a burrow is consolidated into the river-bank. When the platypus has burrowed about six inches, it packs the loose soil by contorting its body and pressing against the sides, at the same time beating the floor with its tail. The width of the excavation is about double that of the finished burrow, that is to say, the earth excavated is tamped into about half its original bulk. . . .

The nesting-chamber is generally placed at the extreme end of the burrow, though sometimes a blind branch is carried on beyond it. . . . In this chamber a nest is constructed, a variety of materials being used, the nature of which depends upon the locality. . . .

As soon as the nest is completed, and before the eggs are laid, the most remarkable habit of all comes into evidence—that of plugging the burrow. . . .

The mining term "pug" seems appropriate to the earth composing

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these plugs, and "pug-pits" to the cavities from which it is derived. I therefore propose to use these terms. What apparently happens is this. When the female has completed the nest to her satisfaction, she goes to the entrance of the burrow, and, turning, re-enters it. At a varying distance from the entrance she excavates a chamber opening off the side of the tunnel and compacts the earth so obtained into a pug, which is always placed close to the first pug-pit, and between it and the entrance. Proceeding towards the nest, she excavates a second pug-pit in the same way, compacting the pug behind her, and so on, without having to turn once from beginning to end. I have found from two to nine of these pugs in different burrows, the usual number being three. The pits would seem to occur indifferently on either side of the burrow, but I have noticed that the latter usually changes direction immediately after a pug. This device has nothing to do with preventing the entry of ordinary flood-waters. The nest is almost always placed at a sufficient height above water-level to escape these, and the platypus can easily break out a new entrance anywhere it pleases. It is obviously a cunning device, partly for protection from enemies, but principally for securing ideal brooding conditions. . . . A final pug is always placed near the entrance to the nesting-chamber. . . .

My experience goes to show that the female . . . digs through and replaces the pugs whenever she leaves the nest or returns to it.

Although they may sometimes be found walking on the surface of the ground the duckbills appear to pass most of their lives in burrows, either the long nesting burrows or the shorter ones used as dwelling places. All of their food, however, is obtained in the water. About the feeding habits Mr. Burrell tells us:

The food of the platypus . . . consists of immature molluscs, aquatic worms, the aquatic larvae of many insects such as dragon-flies, caddis-flies, may-flies, and the like, the larvae and perfect insects of groups such as the water-beetles and water-fleas—which are wholly aquatic—bottom-feeding water-bugs, and such crustacea as inhabit the bottoms of streams. This food is taken in with a certain quantity of mud or sand, which . . . appears to be absolutely essential for the purpose of mastication. The living prey is killed while held in the long horny ridges situated in the anterior part of the mouth-cavity, and is passed rapidly backwards, being prevented from reaching the gullet by the bulbous hinder end of the tongue, and directed to one side or other by the tooth-like projections at the base of the bulb. . . .

At the surface the animal chews the results of its catch in a leisurely

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manner, its jaws working laterally like those of a cow when chewing its cud; having swallowed the contents, it dives in search of more. In diving, the head is first immersed by bending the anterior half of the body downwards and almost simultaneously humping the back. The head is then flexed violently against the chest, giving a very powerful downward thrust comparable with that produced by a crayfish through the sudden flexure of its abdomen. This carries the body below the surface, a process which is aided by an upward thrust of the muscular tail. . . . In this somewhat constrained position it "bobs" along the bottom of the river, testing every part with its tactile muzzle. It has every appearance of having to work hard against a natural tendency of the body to float to the surface. After two or three minutes it raises its head, relaxes the tense attitude of its body, immediately begins to float upwards, and hauls itself to the surface hand over hand by means of the webs of the fore-paws. . . .

. . . When the platypus is definitely on the move, it swims fairly rapidly at the surface, and frequently raises its head out of and parallel with the water, so that it looks rather like a duck. . . .

During an experiment which I made in September 1910 to test the appetite of an adult platypus, I found that in the space of 72 hours it ate 70 ten-inch red worms (resembling an ordinary lead pencil in both length and girth), 10 ground-grubs, and 600 salt-water prawns (of the size usually bought in packets as bait). The record for one night was:—red worms, 30; prawns, 300.

The manner of constructing the nesting burrow is well known, and the general course of the reproductive process is understood; but much remains to be learned about the duckbill's breeding habits. From Mr. Burrell's account we quote as follows:

It does not seem that the platypus displays anything of that affection for its mate which is so characteristic of the behavior of birds and higher mammals. The period during which the mated pair are together is short. . . .

Nor would the female platypus seem to show any actual affection for her offspring. She uses great cunning to keep them safe, and sees to their physical well-being with meticulous care, reducing herself to a state of emaciation and exhaustion in the process. But she makes no attempt to stay by and defend them when a burrow is opened up, her chief anxiety being to escape. I have never known a female in the burrow to show fight, or attempt resistance of any kind. . . .

Incubation is carried out by the female alone. During many years of observation no male has been found in a breeding-burrow. . . .

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On one occasion I was fortunate enough to catch a mother-platypus napping, and she did not wake until an attempt was made to insert a thermometer into the middle of her curled-up form. Her tail was turned up over her abdomen, holding against it two 65mm. young. I am convinced that the eggs are held during incubation in a somewhat similar manner, and that their cohesion supports this view. . . .

The hatching process has not been observed completely. The shells from which the young have hatched are always found in the nest in a flattened condition. On relaxing them in warm water, months later, I have found that they can be made to resume their original shape. . . .

The young, when first hatched, show few of the characteristic features of the adult platypus. There is no sign of the curious muzzle. . . . Indeed, except for the flattening of the rudimentary tail, and the shortness of the limbs, with their even fingers and toes, the young platypus has little to distinguish it upon casual examination from any early mammalian foetus. It grows into characteristic platypus form at a later stage.

The most remarkable and mysterious feature about the baby platypus is that it is not suckled at all by the mother for some days after hatching, for the very good reason that the maternal mammary glands are not yet actively functional. Investigations of this extraordinary phenomenon have advanced far enough to place the matter beyond doubt.

On account of its peculiar feeding habits and voracious appetite, the duckbill is not easily kept in captivity. Mr. Burrell, however, finally had some success in his efforts in that direction, while in 1922 Mr. E. S. Joseph managed with great difficulty to transport a living individual to New York. It arrived at the zoological park on July 14, and lived there forty-nine days, during each of which it was on exhibition for one hour.

CHAPTER X

POUCHED MAMMALS

SCARCELY less unusual than egg laying is the habit that some mammals have of rearing their young in a special pouch or pocket of skin, which covers the nipples, on the abdomen. Perhaps the most widely known of these pouched mammals, or marsupials, are the kangaroos (of Australia) and the opossums (of the southern United States); but no acquaintance, however complete, with these two animals would give any idea of the great variety of bodily form that we find among the pouch bearers or the striking peculiarities in habits shown by different members of the tribe.

Marsupials come into the world in the usual mammalian fashion; but the organ by which the embryos are nourished before birth is so rudimentary that the young are born in an extremely undeveloped state. Immediately after birth these little helpless creatures begin to climb unaided up through the fur on the mother's abdomen and into the pouch, where each seizes a nipple in its mouth and remains firmly attached thereto until a long process of further growth at last enables it to begin its truly separate life. Until a few years ago it was not known how the young reached the pouch, and many strange ideas about the way they arrived there naturally grew up. When the young of a kangaroo three or four feet long and as heavy as a mastiff first appear in the pouch they are not much larger than good-sized lima beans, thus conspicuously smaller than the newborn puppies of any dog. Moreover these tiny young are

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usually found so securely fastened to the long, tubelike nipples of the mother that their mouths bleed if they are roughly pulled off (Plate 101). Therefore they are popularly supposed to have grown from the tips of these nipples like cherries dangling on slender stems. The truth of the matter is told by Le Souef and Burrell along with some other details of this surprising chapter in natural history. They write, in "The Wild Animals of Australasia":

When the young kangaroo is born its forelegs and head are disproportionately large and mobile, and it is able to make its way through the hair to the pouch, and then fasten itself to the nipple. The nipple at this time is pointed and firm, but when it enters the little one's mouth it softens and enlarges, filling the cavity so that it cannot be detached without rupturing the parts. The young stays in this position, closely enfolded by the walls of the pouch, for about four months, by which time it has grown to its normal shape and developed a coat of hair. It is then able to take some interest in outside life; its head may be seen protruding from the pouch, and perhaps nibbling the grass as the mother moves about. Later the youngster comes out, and, like all young things, scampers about, enjoying its liberty, but ever ready to scramble "home" again if danger threatens.

According to these authors the actual progress of the newborn kangaroo to the pouch has been witnessed on at least three occasions, from reports of which we extract the following information: The fetus at birth measures about one and a third inches in length; it looks like a piece of raw flesh; the tail and the hind legs are undeveloped, so that the hinder parts of the animal have the appearance of a red grub; the claws are apparent in the fore legs, and the embryo seems to adhere pretty firmly to the mother's fur; it seems to move upward instinctively and requires roughly thirty minutes to reach the pouch; it moves the head from side to side constantly during the climb; the mother pays no attention to her offspring as it makes its way to the pouch. The young of American opossums have been seen to be born and make their way to the nipples in just the same manner.

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The story is thus completed by Professor Wood-Jones:

When once the young has grasped the nipple, its mouth becomes adapted to its circular form, and instead of the gape between the lips being slitlike in shape it becomes rounded. As John Hunter said, "the sides of the mouth are united something like the eyelids of a puppy just whelped." The nipple, which passes far into the mouth of the embryo, dilates at its tip and so cannot be pulled from the mouth without causing some injury to the sealed lips. As the young marsupial grows larger the fusion of its lips becomes undone—as the eyelids of a puppy part when the eyes open—and then the nipple may be freely withdrawn from the mouth.

Grouped together and separated from all other mammals by this peculiar method of reproduction, the marsupials have pursued a varied course of racial development, which has resulted in bringing many strikingly diversified creatures into existence, some of them curiously like forms that have been evolved by the placentals. But for some unexplained reason the marsupial method of reproduction has always been associated with low brain power. Therefore we find that the brain cavities in the skulls of marsupials are regularly smaller than those in the skulls of placental mammals of equal size, and also that whenever marsupial and placental races of mammals equal to each other in muscular strength and similar in habits come into competition in the struggle for existence, the marsupial loses the game and forfeits its life.

It must not be supposed, however, that this difference in brain bulk has always existed. We have fossil skulls of marsupials dating from the very dawn of the Age of Mammals. They are essentially similar to the skulls of our common opossum, with brain capacity not obviously different. But at this early time and for a considerable period thereafter the brains of placental mammals were almost equally small, though they evidently had the latent ability to grow, while the brains of the marsupials had not. For, as we read the records left by the two lines in successively younger rock layers we find that the brain in succeeding generations of the placental mammals



Pouch of a large kangaroo with the outer skin wall cut and turned back to show a young one attached to a nipple. Natural size. This animal died in the National Zoological Park. Specimen in the National Museum



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steadily increased in bulk while the brain in marsupials remained stationary in size. We also find that the marsupials, simple forms of which probably once had a world-wide distribution, gradually disappeared as the placentals increased in abundance, until finally they were left in only two regions, Australia and the warmer parts of America. Both Australia and South America have long enjoyed partial or entire separation from the rest of the world and have thus been able to give their marsupial inhabitants freedom from the danger of extermination by the placentals. And this friendly isolation has been longest and most complete in Australia. Here the marsupials have peacefully and in greatest detail worked out their problems of making the most of the many opportunities for following special modes of life—as runners, jumpers, burrowers, climbers, flesh eaters, insect eaters, or plant eaters—presented by the varied kinds of environment in which they have found themselves, and the varied possibilities of adaptation to the needs of these special modes of life presented by their own bodily structure. In dealing with these problems they have solved many of them in the same way that the placentals, independently and in other parts of the world, have solved their similar problems. Bodily forms that strikingly resemble each other in their general make-up have thus come to exist in mammals unrelated otherwise than by the bond of some very remote, egg-laying (or perhaps reptilian) common ancestry. This phenomenon, called by some writers “parallelism” and by others “convergence,” is frequently met with among animals of every sort. Often it is very puzzling because it makes creatures look and act alike without being at all nearly related; but in the whole animal kingdom there is probably no more striking example of it than the one presented by the marsupial and the placental mammals.

We have already seen that, of the two groups, it is the placentals which have shown the greater ability in the

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important matter of brain development. We shall now find that they have also excelled in modifying their bodily structure into the greater variety of types. For, unlike the less versatile marsupials, they have been able to produce horns, hoofs, quills, bony or horny plates, fins, wings, hands, and prehensile proboscides. Among them only, therefore, do we find ungulates, porcupines, armadillos, pangolins, whales, seacows, seals, bats, primates, and elephants, whose structure is characterized, respectively, by just these anatomical features. But, though outdone by the placentals, the marsupials have shown themselves to be endowed with remarkable powers of invention. They have produced their own unique types, among them the kangaroo, honey-mouse, bandicoot, numbat, the rhinoceroslike (though hornless) extinct *Diprotodon*, and the great shearing-toothed extinct *Thylacoleo*.

Good descriptions of the Australian marsupials have been recently published by Le Souef and Burrell and by Wood-Jones. From the writings of these authorities we have, for the sake of brevity, freely paraphrased the following accounts of some of the more interesting of these creatures. We shall take up first the kinds that are most unique and then pass to those whose development has run parallel with familiar placentals.

THE KANGAROOS

The kangaroos usually seen in zoological gardens are large animals, but there are actually many small kinds, ranging down to the size of a hare. These smaller kangaroos are generally known as wallabies.

In the varied landscape of Australia the bodily shape and color of each kangaroo species harmonize with the local environment. Thus the gray kangaroo lives in the open forest; the brown fur of the black-faced kangaroo merges into the shades of the denser thickets; the red kangaroo has its home in the open plain of the interior,

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more often than not on red soil; while the powerful wallaroo frequents the rough hillsides. The wallabies keep close to cover, hiding during the day in the undergrowth and feeding at night on the edge of the thickets.

To quote Le Souef and Burrell:

As it is not very easy for these animals to travel over rough country or through thick undergrowth, the kangaroos sometimes, and the wallabies often, form tracks through the scrub which give access from the thickets to the open ground, or from one feeding-spot to another. These tracks then take the easiest grades, and often run across the slope of a hill. When travelling slowly these animals move over the ground in a manner peculiar to themselves, swinging the legs forward between an arch formed by the arms and the tail. In this manner the average kangaroo will cover about three feet at a stride. When the animal hops the body is inclined forward and balanced on the hind-legs by the tail, which does not touch the ground. At a slow pace the distance covered is from four to six feet, but this rapidly lengthens with the speed, and a large active animal will easily cover twenty-six feet at a stride. Such a jump, however, is not made every time, for the distance varies with the ground, and one hop may be ten feet shorter or longer than the next. A hunted kangaroo has been known to clear a nine-foot fence, but very few will attempt anything over five feet.

A male kangaroo is a clever and determined fighter, and when brought to bay by dogs will put its back against a tree or rock, and be ready for all comers. Woe betide the rash hound that rushes in impetuously to the attack, for the powerful hind-feet, armed with spear-like claws, can be used with deadly effect, and will rip open the flanks of the enemy in a flash.

Kangaroos usually lie up during the day in some sheltered spot, moving off to the feeding grounds in the late afternoon, the males in the lead and the females and young behind. Permanent resting places are indicated by circular holes in the ground, in which the animals dust themselves and lie more comfortably. The voice is a hoarse cough. The males among the larger kangaroos often box, seemingly for fun. They grapple and cuff one another about the head and shoulders and deliver vigorous kicks to the body with the hind limbs. The rounds last about three minutes, with a rest of about the same time between.

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Enormous numbers of kangaroos are killed for their skins. In dry regions hunters simply wait for them at the water holes, to which thirst eventually drives them in spite of all their wariness.

Kangaroos are so obviously adapted to living on open ground that it is no small surprise to find that some of them pass much of their time in trees, where they climb



FIG. 9. Tree kangaroo, a marsupial jumper that has become arboreal

about freely among the smaller branches in search of leaves and fruit (Fig. 9). The peculiar foot structure of the ordinary kangaroos gives unmistakable evidence that the ancestors of these plains dwellers were once arboreal; in the tree kangaroos we can read by the foot structure the story of a gradual abandonment of the strictly terrestrial mode of life and a partial return to the tree

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tops. To fit them for this reversion to earlier habits, the claws of the tree kangaroos have become sharpened, their foot pads roughened, and their tails lengthened. Two arboreal species are found in Australia and several others in New Guinea.

Frequenting the mountain forests rather than the coastal scrubs, the tree kangaroos are reported to spend most of their time on the ground, ascending the trees only to feed or if pursued by dogs. Lumholtz's tree kangaroo is said to be able to jump from a great height and run rapidly on the ground.

From Le Souef and Burrell we quote as follows:

The tree kangaroos will live readily in captivity, but seldom for any length of time; evidently they require some special food to keep them in health that can be procured only in their forest haunts. Some kept in the Melbourne Zoological Gardens showed themselves to be apt climbers; they were able to ascend a lead pipe or a hanging rope with equal ease. They always descended to the ground tail first, and hopped like a wallaby, but with relatively smaller strides. At times they naturally walk backward. The small ears have not the power of turning in all directions like those of the genus *Macropus*.

THE HONEY-MICE

No less remarkable than the kangaroos, and utterly different from these large and active jumpers, are the tiny marsupials known as *Tarsipes* or honey-mice (Plate 102, upper), which, with their long tongues, take the honey from flowers after the manner of honey-eating birds. The honey-mouse is about the size of a house mouse and of a general grayish color, the back having three longitudinal stripes of a darker shade. It has a long, prehensile tail, elongated muzzle, and extensible tongue. About its habits and distribution Le Souef and Burrell tell us:

Restricted to a small area of South-western Australia, it lives among the scrub trees, apparently making its home in the nests of birds, and feeding on the nectar from the free-flowering melaleucas

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and banksias. Doubtless, too, it captures many insects attracted by this food-supply.

In captivity a honey-mouse has been observed to sleep during the day and become active at night. It would hang suspended by its tail to a small branch, and suddenly jump to another.

THE BANDICOOTS

The bandicoots form a well-defined group of marsupials without an obvious analogue among ordinary mammals. In a general way some of the larger kinds resemble rabbits (Fig. 10), except that their tails are long; and the

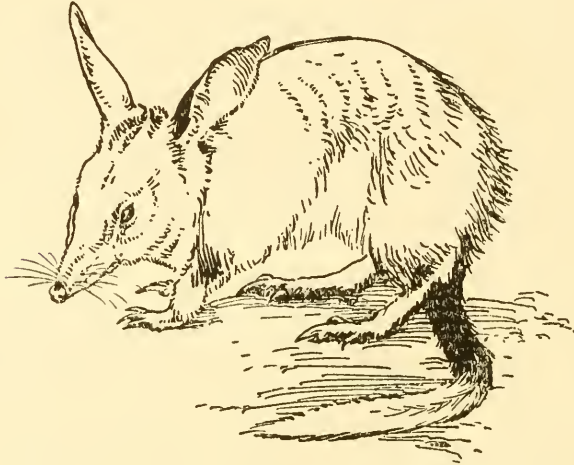


FIG. 10. Rabbit bandicoot. After Le Souef and Burrell

smaller kinds resemble rats, though their muzzles are slenderer and their hind legs longer.

Bandicoots are omnivorous in diet, though the favorite food of the rabbit bandicoots consists of large, white, beetle-larvae. This passion for insects at the roots of plants made them, in the days of their abundance, economic allies of the farmer; though in their excess of



Marsupial contrasts

Upper: Honey-mice. The honey-mouse is a slender, tree-climbing marsupial about the size of a house mouse. Lower: Wombat, a heavily built, burrowing marsupial about the size of a beaver. Specimens in the Public Library, Museum, and Art Gallery of South Australia

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zeal they sometimes did more excavating than was good for the plants.

With their powerful forearms and long strong claws, all the bandicoots are experts at digging for food and burrowing. They live during the day in burrows made in moderately firm soil. It is very little use trying to dig out a bandicoot in loose soil, for it will excavate ahead of the spade and endure after the spader is exhausted.

So great is the rat bandicoot's energy, in fact, that Professor Wood-Jones recommends it rather than the ant to the emulation of the sluggard. "So long as a bandicoot is awake, it is busy," and though crepuscular in habit, it will work through the hottest day at building or repairing its nest.

The rat bandicoot makes a nest by collecting all the grass and dead leaves in an area of vegetation into a large mound. It scratches the grass up by the roots and denudes the ground, but once the vegetation about and in the mound has regrown the nest is hard to detect.

Professor Wood-Jones writes:

No permanent hole is left in the little mound, for the animal burrows in and out at any aspect. Invariably on emerging from the nest it sets about bed making, shaping up the mound and closing over the hole from which it emerged. There is no permanent chamber in these nests; but the animal lies in the middle of the collected material, and if the dome of a newly-made mound is watched, the animal's respiratory movements are easily detected. When it awakes in the evening, a heaving movement is seen in the mound, as though a small earthquake were in progress; the awakened animal breaks out anywhere and immediately starts to repair the damage. Bandicoots seem to have an instinct of the approach of bad weather, for before heavy rain they will add to the nest pile with feverish activity. One that I had in captivity would always leave its open-air nest and retreat to the security of a bed inside a box, and the change of residence was always made in advance of the advent of bad weather.

Their methods of fighting are peculiar. The aggressor will tirelessly follow his victim until he wears it down. . . . When one animal overtakes the other, and presses it to an engagement, the assault is made by a jump and an endeavor to strike with the claws of the hind feet.

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Each stroke carried home removes some hair from the victim's back and scratches the thin skin. This style of fighting may continue for a long while, but, as the less aggressive animal tires, the stronger one will attack with a rapid scrambling motion of its fore feet, inflicting damage by strokes of the strong claws of the manus, the strokes being delivered with lightning rapidity. They seem never to fight face to face, for when the chase leads to such a meeting one instantly jumps over the other, inflicting a blow with the hind foot in passing, and renews the attack from the rear. Only as a last resort, although the whole encounter has been conducted with open mouths, do they start to bite each other.

Le Souef and Burrell say that bandicoots are able to hold their own pretty well against the inroads of settlement, but Wood-Jones holds a less cheerful view, declaring that they are rapidly disappearing over the whole of Australia, however abundant they may still be in certain spots. In view of the economic value of the bandicoots and their engaging and fearless dispositions, their extermination would mean a real loss to the world.

THE NUMBAT, OR MARSUPIAL-ANTEATER

The numbat, in the words of Professor Wood-Jones, "is an animal which possesses the distinction of being so peculiar a creature that it cannot possibly be mistaken for any other species." It is about the size of a large rat; its muzzle is pointed, its tail is long and bushy, and its tongue is extensile like that of an anteater (Fig. 11). The posterior half of the body is marked with dark and light bands arranged transversely. This is a very unusual color pattern, for, in most striped mammals, the markings extend lengthwise of the body. In its cross striping the numbat resembles the Tasmanian pouched-wolf, the tiger, the African banded mongoose, the zebras, and one of the African small antelopes, or duikers. These are all widely unrelated animals, and their similar plan of color arrangement is a striking example of parallelism.

Even more remarkable than its color pattern is the numbat's dentition. The teeth so closely resemble those

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of some very ancient fossil mammals that they have suggested to some writers the possibility that the animal may be an almost unmodified survivor from times that date far back into the Age of Reptiles. On this subject

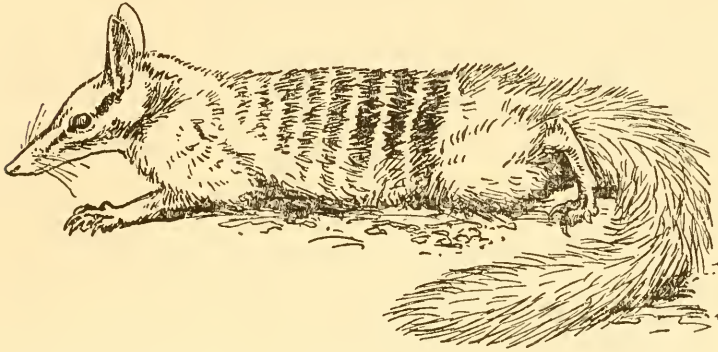


FIG. 11. Numbat, or marsupial banded anteater. After Le Souef and Burrell

Le Souef and Burrell say: "Quiet, inoffensive, without means of defence or offence, it is remarkable that the marsupial anteater has survived through the ages. This could happen only in Australia, where it did not come into competition with the more advanced forms of life." But this seemingly endless hold on existence is about to be broken, and it can be only a few years before the numbat will have become as much a creature of the past as the giant reptiles with which it may have once shared the earth. What is now going on is graphically told by Professor Wood-Jones:

The extermination of the numbat is a tragedy in which man has probably played very little conscious part; it is no tale of ruthless slaughter for gain, such as is being rehearsed to-day in regard to the Australian fur-bearing animals, nor is it a case of determined persecution as is the case with the Tasmanian Devil. *Myrmecobius* is an animal which is probably phylogenetically senile, which has become highly specialized in function and degenerate in some details of struc-

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ture. Added to this is the fact that its home is invariably made in the hollow of a fallen tree or a rotting log. Accidental bush fires and the intentional burning off of country seem to have found the numbat an easy victim, and they have exterminated it as they are exterminating other small terrestrial marsupials. There is no escape from a bush fire for the numbat. It does not excavate deep burrows, it does not climb, it is not fleet of foot:—as its log home burns, it perishes.

Unfortunately no good life history of the numbat has ever been written; and the time may now have passed when the necessary observations could be made.

When disturbed it at once makes for shelter, running with successive leaps, with the tail a little elevated, every now and again raising the fore part of the body and resting on its hind feet. Before entering the hollow, it invariably sits up and looks around to ascertain the reality of approaching danger. When caught it is harmless and tame and never attempts to bite.

DIPROTODON, THE GIANT MARSUPIAL

During the Pleistocene period, and thence on almost to historic times, Australia was the home of the *Diprotodon*, a veritable giant among the pouched mammals. *Diprotodon* had a skull measuring about three feet in length, and its body was proportionately large, making it a creature as large as a good-sized rhinoceros. In form, however, it was more like a wombat. *Diprotodon* was related to the kangaroos, but it had characteristics also of other groups of marsupials; and, unlike the leaping kangaroos, it had heavy-boned limbs of approximately equal length and adapted solely for walking.

A somewhat less gigantic extinct marsupial, *Nototherium*, was a contemporary of *Diprotodon* in Australia. This animal combined some of the characteristics of the kangaroos with some of those of the koala.

That *Diprotodon* and *Nototherium* were herbivores is conclusively shown by the structure of their teeth. Their extinction probably came about partly as the

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result of their extreme specialization in size and partly because the gradual drying of the Australian climate, which has long been in progress, brought about a fatal reduction in their food supply. The final extermination may have been hastened by early man.

THYLACOLEO, THE MARSUPIAL-LION

Associated with the giant diprotodonts during Pleistocene times, was another strange Australian form of

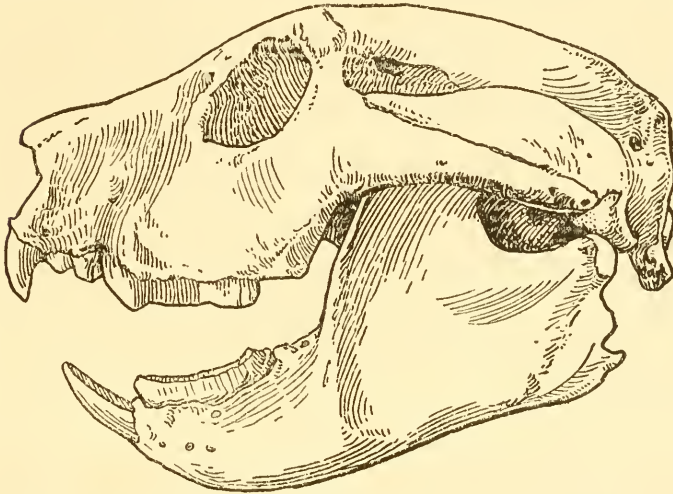


FIG. 12. Skull of *Thylacoleo*, an extinct Australian mammal, once thought to be a fierce flesh eater but now regarded as more probably a peaceful vegetarian. After Anderson

now extinct marsupials, not so large as *Diprotodon* and belonging to a quite distinct group of the order. Because of the peculiar modification of their cheek teeth it has been supposed that the marsupials of this group were flesh eaters. Owen, who first described them, thought that they were carnivorous when he proposed the name *Thylacoleo*, meaning "pouched-lion." But the canine teeth, the chief weapons of carnivorous mammals, are

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wanting in the lower jaws and are very small in the upper jaws, while a single upper and a single lower pair of incisors are greatly enlarged. Because of this marked development of the incisor teeth some authors have placed *Thylacoleo* in the diprotodont family, whose members so far as known are all plant eaters. A single cheek tooth in each jaw is greatly enlarged to form a powerful cutting or shearing pair (Fig. 12). Such teeth look as though they would be efficient implements for cutting flesh and sinew; but to what special kind of vegetable food they might have been adapted is difficult to conjecture. Since nothing is known of the ancestry of these interesting beasts this anomaly of tooth development may never be satisfactorily explained.

With the extinct *Diprotodon* and *Thylacoleo* we have completed the list of marsupial experiments along those lines of structure and adaptation on which it might be said that the placental mammals have not chosen to venture. We shall now turn to some of the more conspicuous instances of development along lines that have been independently followed by both pouch bearers and placentals.

THE WOMBATS

The wombats (Plate 102, lower) are thickset, heavily built ground dwellers, about three feet in length, with rudimentary tail and strong, short feet. In general appearance they suggest large marmots; and, like the marmots, they live in burrows and feed on grass. But more extraordinary than their general resemblance to one of the rodents is their remarkable parallelism to all the rodents in skull and teeth—a peculiarity that is shared by no other pouch bearer. In the words of Professor Wood-Jones:

The Wombats differ from all other living marsupials in having only a single incisor tooth upon each side of both the upper and lower jaws, and in having all the teeth rootless and persistently growing. . . .

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The dental condition of the wombats shows the most remarkable parallelism in development to that of certain of the rodents, and affords a most striking example of the similar modification of structure in response to similar demands of function. . . .

Wombats are nocturnal animals, shy and cautious, and exceedingly difficult to observe. . . .

Concerning the disposition of the animal itself, there is, first, the excellent and historical account of Bass's capture of *ursinus* on Cape Barren Island. The capture was effected easily, for "by placing his hands under its belly, he suddenly lifted it from the ground and laid it upon its back upon his arm as a child would be. It made no noise, nor any effort to escape, not even a struggle. The countenance was placid and undisturbed, and it seemed as contented as if it had been nursed by Mr. Bass from its infancy. He carried the beast upwards of a mile, and often shifted him from arm to arm, sometimes laying him upon his shoulder, all of which he took in good part until, being obliged to secure his legs while he went into the bush to cut a specimen of a new wood, the creature's anger arose with the pinching of the twine. He wizzed with all his might, kicked and scratched most furiously, and snapped off a piece from the elbow of Mr. Bass's jacket with his grass-cutting teeth. Their friendship was here at an end, and the creature remained implacable all the way to the boat, ceasing to kick only when he was exhausted."

THE KOALA

In the Australian koala (Plate 103) we find a marsupial that has become specialized for a life of tree clinging in somewhat the same manner as the South American sloths. "The quaint koala, or native bear," Le Souef and Burrell remark, is "a creature which, perhaps, holds the affection of Australians more than any of their wild animals—a fact for which its innocent, babyish expression and quiet, inoffensive ways are largely responsible." The practical value of this popular affection to the animal is graphically told by Professor Wood-Jones:

. . . probably no animal has been so ruthlessly slaughtered in order to satisfy the demands of the fur trade. . . . That this deplorable slaughter still goes on is evidenced by the fact that in the two years 1920 and 1921 Osborn and Anthony have ascertained that the huge total of 205,679 koalas were killed for the fur market. . . .

It is extremely tenacious of life, even when mortally wounded,

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and horrible cruelties have been committed and recounted by those who have slaughtered them wholesale for the sake of their pelts. Indeed, one may say, on humanitarian grounds, that not only should the slaughter of the koala for the fur trade be prohibited because the animal is eminently one to protect and not to exterminate, but it should be prohibited because, like the slaying of seals, it is the most brutalizing occupation that a human being can undertake.

The koala, according to Wood-Jones, may be said to spend its whole life clinging to and feeding upon the great eucalyptus trees. By overspecialization it has become the slave of its environment, and can not make itself at home in a new one.

The animal is wholly inoffensive and makes an affectionate though difficult pet. In fact, when brought up in captivity it dislikes being left alone and becomes an exacting care. Because of its almost exclusive diet of tender eucalyptus shoots, it smells strongly of the pungent oil that they yield. In view of the koala's sturdy build and strongly curved claws, the tendency of tame individuals to climb up the nearest human being may be embarrassing.

In spite of its specialization for an arboreal existence, the koala can shuffle along on the ground at a good pace. The old males have a tremendous bray, but the common vocal expression is a hoarse grunt.

The koala bears only one offspring at a birth. The youngster clings to the fur of its mother's back for a long while after leaving the pouch.

THE FLYING PHALANGERS

Lightly floating through the air from tree to tree, buoyed up by extended parachute membranes, one of the Australian flying phalangers might readily be mistaken for a flying squirrel. But these creatures are true pouch bearers, and their resemblance to the familiar northern rodent is purely the result of a parallel and independent



Koalas, or Australian "bears." The koala is a thickset, tree-climbing marsupial, somewhat larger than the American raccoon. Group in the Public Library, Museum, and Art Gallery of South Australia

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development of skin folds extending out from the sides of the body between the fore and hind legs (Fig. 13).

One of the flying phalangers has the distinction of being the smallest known parachuting mammal. Its size is about equal to that of a house mouse, and its

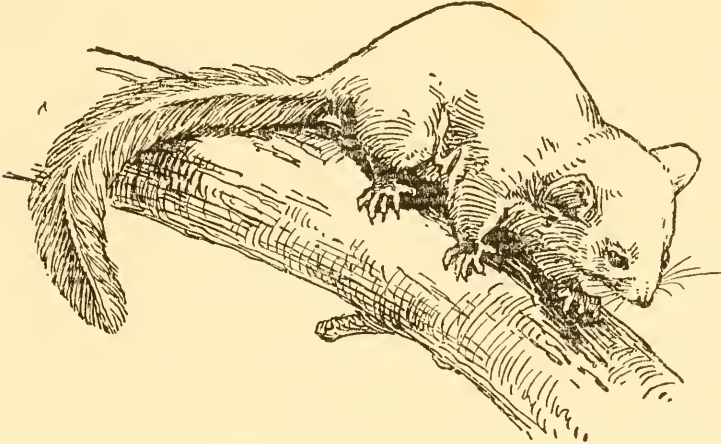


FIG. 13. Pygmy flying phalanger, about the size of a house mouse. After Le Souef and Burrell

name is *Acrobates*. In small family groups it haunts the eucalyptus forests of eastern Australia, keeping to those trees that have a white, smooth bark. The family secretes itself in a small hollow from two to fifty feet above the ground. The globular nest usually consists of eucalyptus leaves. When the animals are at home the entrance is cleverly closed. *Acrobates* feeds on insects, probably those scale insects that secrete a sugary substance. In captivity it is fond of sugar, but its favorite food is the termite, or white ant.

The common flying phalangers are as large as medium-sized flying squirrels. Clothed in long, silky hair, softly and delicately colored, and with large liquid eyes, they are, perhaps, the prettiest and most graceful of the

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Australian native mammals. In the mating season—about April—their startling screech, followed by a series of down-the-scale gurgles, can be heard ringing through the air, but at other times they are silent and difficult to locate when out feeding at night.

Le Souef and Burrell quote an interesting account, from one of their correspondents, of the capture and habits in captivity of a yellow-bellied flying phalanger:

My twelve-year-old son was coming home from school, when he noticed a great commotion round a dead tree. Riding across, he saw two full-grown flying squirrels being attacked by butcher-birds, magpies, and a crowd of noisy miners. Just as he arrived, one squirrel floated down to a lower branch, and, struck by a swooping bird, hit her head on a branch, and fell to the ground, when the baby fell from her back. The mother raced up a near tree and floated off to another. So the boy put the young one in his pocket and brought it home. Fed on milk, it thrived, and was especially fond of my daughter Marjory, who brought it up. Recently we put "Squirry" on a tree-stump 12 feet high, and six of us stood around; the animal looked at us all, then floated down on to Marjory. It was put up again and we changed positions, with the same result!

THE CARNIVOROUS POUCH BEARERS

At least three different kinds of marsupials have become flesh eaters and have developed bodily forms that make them resemble well-known types of placental carnivores. The small marsupial "native cats" are somewhat like martens in general build; the thylacines resemble wolves; while the "Tasmanian devil" is a heavy-bodied creature which, in some of its habits and in the form of its skull, strongly suggests the badgers. Finally, it seems not improbable that in northern Australia there exists a carnivorous marsupial resembling a large and formidable cat.

The ordinary "native cats" are black or dark brown, spotted with white (Fig. 14). There are several kinds, one as large as a small fox, the others smaller. All are active and aggressive killers. The fierce spotted-tailed

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dasyure is powerful enough to kill wallabies and fairly large birds, but as its short legs rob it of speed, its chief fare doubtless is such small fry as can be taken by surprise in the bush.

The smaller dasyures, common to all of Australia and Tasmania, are nocturnal, spending the day in hollow logs,



FIG. 14. Large spotted-tailed dasyure, or Australian "native-cat." After Le Souef and Burrell

holes in the ground, and similar hiding places. They will enter houses in search of food and at times do damage to poultry, though they prefer smaller game.

Concerning reproduction in these native cats, Le Souef and Burrell have this to say:

From four to seven young are born in May or June. A female caught in Taronga Park on May 10 had seven young about the size of peas attached to the teats. By July 30 they were the size of mice, their naked skins showing the spots through. On August 10 they were showing outside the pouch, but the eyes were not open. They were, however, open on the 25th of the same month, and it could be seen that the young varied in colour—there were two blacks and three greys, two having disappeared. These animals can be handled with impunity, provided no quick movements are made.

The marsupial-wolf, or thylacine, is doglike in size and in general form. It is yellowish-brown in color, with from sixteen to nineteen blackish-brown transverse cross

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stripes on the back (Fig. 15). The length of its head and body is about three feet. It is now confined to Tasmania, though formerly it had a wide range on the mainland of Australia, where its extermination, which

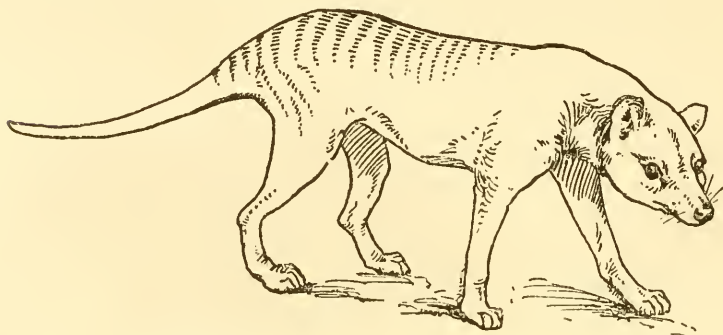


FIG. 15. Thylacine, or marsupial-wolf. After Le Souef and Burrell

took place before the arrival of European explorers, may have been due to the introduction of the dingo. About the thylacine Le Souef and Burrell tell us the following:

The thylacine hunts singly or in pairs, feeding on wallabies, small rodents, and birds. When a wallaby is put up it is not chased at breakneck speed, after the manner of a dog, but the pursuer merely trots along the scent until the quarry shows signs of exhaustion; it then quickens its pace, rushes in, and secures the victim. The wolf very rarely takes a dead bait, and seldom returns to a carcass. It is by no means fast, and lacks the easy paces of the Canidae. It usually trots, or, if pressed, breaks into a shambling canter. When excited it makes a series of husky, coughing barks, the breath being indrawn with a wheeze.

Although quiet and inoffensive as far as man is concerned, the thylacine can put up a good fight against a dog, as the following incident, related by Mr. Hugh S. Mackay, will illustrate: "A bull-terrier was once set upon a wolf (thylacine) and bailed it up in a niche in some rocks. There the wolf stood, with its back to the wall, turning its head from side to side, checking the terrier as it tried to butt in from alternate and opposite directions. Finally, the dog came in

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close, and the wolf gave one sharp, fox-like bite, tearing a piece of the dog's skull clean off, and it fell with the brain protruding, dead."

The thylacine usually produces four young. These are carried in the pouch for about three months, and then deposited in a snug shelter until able to take the field on their own account.

The Tasmanian devil is another carnivorous pouch bearer that once enjoyed a wide range in continental



FIG. 16. Tasmanian devil, about the size of a badger. After Le Souef and Burrell

Australia but is now restricted to the island from which it takes its name (Fig. 16). In size it is about equal to a large cat or small badger. Its form is heavy; its bushy tail, moderately long; and its color black, with white patches on the throat and on the back, near the base of the tail. The general aspect of the skull is curiously badgerlike. Exactly why this animal should have been given its rather sensational name is not obvious.

The devil is very like a raccoon in its habits, according to our authorities, and makes up for its slowness by strength and cunning. Though capable of pulling down larger game, its usual prey consists of small wallabies,

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rat kangaroos, ground birds, and similar creatures, which it locates with its keen sense of smell. It eats carrion indiscriminately. It hunts in the afternoon and evening, lying in logs or under other cover during the day. Young individuals can climb trees.

On the mating habits of the animal, Le Souef and Burrell quote a very interesting account from a correspondent:

"Two devils were kept together as a pair. These showed no disposition to breed until April; then the male would not allow the female to come out of their little den; if she did he would immediately attack and drag her back. When I called it was pitiable to hear her whining, but it was of no avail, for the male was a relentless tyrant, and kept her in seclusion for ten or twelve days. Then, early in May, he allowed her free once more. Thence onward the balance of power was on the side of the female. She constantly resented his approach by biting and snarling, as though she instinctively felt that he might do the young some injury. From now on her pouch was carefully examined every day, but it was some time before I could be sure that it was gradually enlarging. Matters went on much in the same way until late in September, when, to my delight, a tail or part of a small body could be seen sticking out, more especially when the mother sat up to wash her face. Unlike the domestic cat, the devil uses both paws for washing, placing them together, and forming a cup-like depression, which is thoroughly licked and well rubbed over the face.

"At the end of September the mother was noticed to be carrying large bunches of straw in her mouth, evidently seeking a place in which to make a bed for her young. From observations I have come to the conclusion that about four and a half months elapse from the breeding season until the young are able to leave the pouch."

Mrs. Roberts found that these animals, reared in captivity, make delightful pets, being frolicsome and affectionate. They are fond of bathing, and also of basking in the sun. Adult animals caught wild are docile when handled.

The striped marsupial-cat, reported from the mountains of Cape York Peninsula, northern Queensland, is at present a mystery animal, no specimen of it having yet been examined by a naturalist. This is explained by the comparative inaccessibility of its range. Nevertheless, the accounts of it have such an appearance of authenticity

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that Le Souef and Burrell give the creature a place in their book, regarding it as a marsupial because, apparently, it can not live in competition with the dingo: it inhabits the only country that the wild dog can not penetrate. According to the accounts of the few persons who have seen this creature, it stands as high as a medium-sized dog and is striped—tiger-fashion—in black and gray. Its ears are sharp and lynxlike, and its head is tiger-shaped. Its paws are armed with lancelike claws of great tearing strength.

THE PHALANGERS

The common phalangers, known as “opossums” in Australia, are so modified that, with the prehensile tail, dense fur, short head, and tree climbing, frugivorous habits that characterize them (Fig. 17), they remarkably parallel the tropical American kinkajous. Or perhaps it would be more correct to say that the kinkajous are the imitators, for they are carnivores that have taken to a frugivorous diet and a life in trees, while the phalangers belong to a large group whose members normally have these food habits.

The recent history of the Australian “opossums,” as told by Professor Wood-Jones, presents a welcome contrast to that of so many Australian mammals: their extinction appears not to be imminent. The “opossum” seems to be the only marsupial that is successfully adapting itself to modern conditions and that lives as well in the shelter of suburban

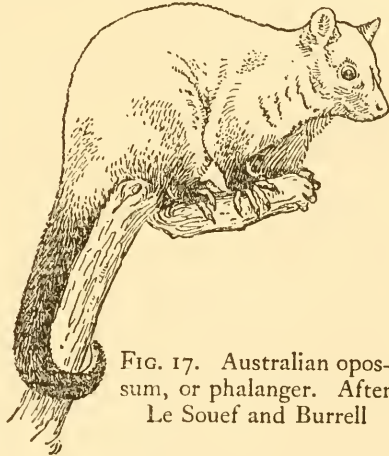


FIG. 17. Australian opossum, or phalanger. After Le Souef and Burrell

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areas as in the wild. For its nests it has even learned to substitute cottage eaves for holes in eucalyptus trees; and in treeless country it will nest in rabbit warrens. This habit has given rise to the foolish superstition that the "opossum" and rabbit interbreed.

But this remarkable adaptability does not spring from superior intelligence, for the phalanger is an inoffensive and stupid animal, readily tamable. When chased and captured it will bite and scratch and defend itself stoutly, but utter no cry. In its own affairs, however, it is very noisy, uttering a hiss that becomes increasingly high in pitch. During the frequent fights and altercations among the phalangers the hiss may rise to a raucous cry. The cry of the young so resembles that of the common South Australian tree frog as to be indistinguishable.

THE POUCHED-MICE

Throughout the greater part of the world, including most of Africa, Europe, Asia, the Malay region, North America, and the northwestern part of South America, there is abundantly represented a group of superficially mouselike placental mammals called shrews. Their existence and their remarkable success in the business of maintaining their race may be said to center about their exploitation of the opportunities offered by rotting wood and the insects that inhabit it. Small size, dense fur, pointed muzzle, teeth fitted for chopping the soft bodies of insects, an aptitude for superficial burrowing in vegetable loam (but not for the deep tunneling of moles and gophers)—these are the characteristics that enable the shrews to pursue the course of their inconspicuous but efficient careers. That the marsupial group should have responded to these universally present opportunities by producing creatures that resemble shrews might be anticipated; and, in the pouched-mice of Australia and the caenolestids of the Andean region we find the looked-for response.

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The pouched-mice, or "phascogales," are small animals whose length (head and body combined) ranges in different kinds from about three to six inches (Fig. 18). They have a slender muzzle, bare at the tip like that of the shrews, but less sharply pointed. Professor Wood-Jones speaks of one species thus: "A useful insectivorous and carnivorous creature, it is too small and obscure in its ways to attract attention, and but for being occasionally brought into houses by cats it would usually escape notice,"—words that would apply equally well to most of our common shrews.

Although largely insectivorous, the phascogales will eat small vertebrates, such as birds and lizards. Some species are particular enemies of rats and mice, whose numbers they reduce; and the brush-tailed phascogale has been blamed for killing fowls in hen roosts.

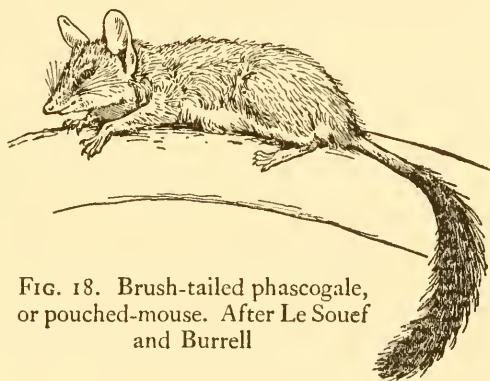


FIG. 18. Brush-tailed phascogale, or pouched-mouse. After Le Souef and Burrell

Although disease in 1898-1900 rendered the brush-tailed and lesser brush-tailed phascogales scarce, and cats have been very destructive to many kinds, several species still remain numerous. The brush-tailed phascogale is arboreal and behaves very much as does the American gray squirrel. It nests in trees, making a cozy home of leaves, but will use rag or paper. On one occasion when two timber cutters were camped together at Ebor, New South Wales, one missed a pound note. This caused rather a strained feeling between them, until the lost note was found in a phascogale's nest in a tree close by which had been felled for timber!

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THE CAENOLESTIDS

In the Andes, of South America, certain small marsupials, called caenolestids, are even more shrewlike than the Australian pouched-mice. Not only is their size and general appearance suggestive of the larger shrews, but the lower front tooth is elongated in line with the jaw essentially as is that of the familiar insectivore. Not much has been published about the habits of these peculiar little pouch bearers; but the animals evidently pass most of their time on the ground, where they make tunnels just beneath the surface, exactly after the manner of shrews. Their food consists chiefly of insects, but they may be caught in traps baited with meat.

THE JERBOA POUCHED-MICE

The kangaroos are not the only Australian pouched mammals that have become highly specialized jumpers. Kangaroos, as we know, are plant eaters, and their range in size corresponds in a general way to that which we are accustomed to see in dogs. In the desert regions of central Australia a mouse-sized flesh eater, or perhaps more probably an insect eater, *Antechinomys* (Fig. 19), has independently taken to jumping, though in a different way from the kangaroos, with the result that it has developed a form and general appearance curiously resembling the jerboas of Asia and the jumping shrews of South Africa, both placental mammals. Another remarkable fact is that a tribe of placental true mice, *Notomys*, inhabiting these same Australian deserts, has done almost exactly the same thing, although it is a plant eater. This represents a striking example of parallel development.

Incidentally, Professor Wood-Jones finds in the juxtaposition of these two species an illustration of the scarcity in numbers of carnivorous as compared with herbivorous animals; for *Antechinomys* is an animal of the greatest

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rarity, whereas its vegetarian counterpart exists in vast numbers in the same environment.



FIG. 19. Jerboa pouched-mouse, an insect eater of the central Australian desert regions. After Wood-Jones

One observer who has seen *Antechinomys* alive says that it is capable of making a jump of at least six feet, a remarkable distance in proportion to its size.

THE PIG-FOOTED BANDICOOT

Among the mammals with which we are most familiar are those with legs and feet especially adapted to running. Such are the horse—with one hoof on each foot—and the deers, antelopes, and camels—with the hoofs or toe pads in pairs. Marsupials appear to have been more successful in producing jumpers than runners, but among them is found one animal with legs and feet of a truly cursorial type. This is the rare and little known pig-

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footed bandicoot, a creature about the size of a house rat. Its feet (Fig. 20) are greatly elongated and the toes are reduced in number, but the hind legs are not conspicuously enlarged as in the jumping types.

The fore foot has two functional digits like that of a pig, but with the difference that in the pig-footed bandicoot these digits are the second and third, whereas in the pig they are the third and fourth. The hind foot, like that of the horse, has only one digit developed for the purpose of progression and support, but with the difference that in the horse the functional digit is the third, whereas in the bandicoot it is the fourth.

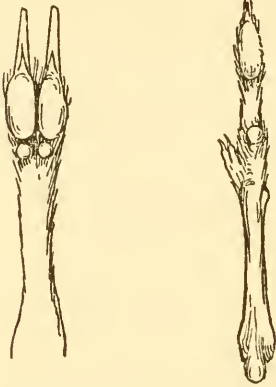


FIG. 20. Fore and hind feet of pig-footed bandicoot. After Wood-Jones

So rare is the pig-footed bandicoot that little is known of its habits. It is not strictly nocturnal. In diet it is omnivorous, but it seems to prefer flesh. It is said to squat in the open with its ears laid back very much after the manner of a rabbit. Two young are produced at a birth, and the breeding season is in June.

THE MARSUPIAL-MOLE

Subterranean life, which has been successfully adopted by placental mammals of several different kinds, such as the insectivorous moles, the rodent gophers, and the little "pichicigo" armadillo, seems to have attracted only one pouch bearer, the remarkable Australian animal known as the marsupial-mole (Fig. 21). In two respects this creature has gone to greater lengths of specialization than any of the placental burrowers; it has developed a thick horny shield on the fore part of its face above the nostrils, and it has so reduced the eye that this organ, represented by a

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mere pigment spot in the embryo, is completely absent in the adult. The skull has a peculiar wedge-shaped general outline like that seen in the placental golden moles of South Africa. Indeed, both the general form and the details of structure in the skulls of these totally unrelated burrowers are so similar that they have been

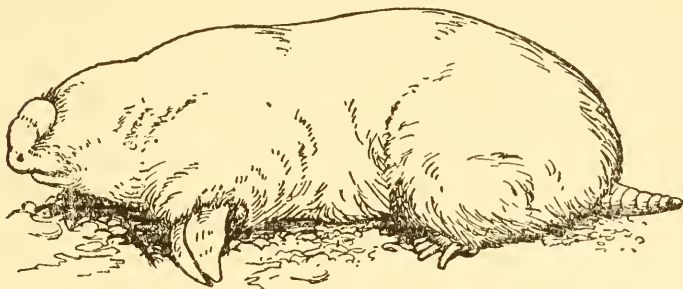


FIG. 21. Marsupial-mole, which is highly specialized for burrowing. The eye is completely absent in the adult

said to represent the most striking example of parallelism known among mammals. The following account of the marsupial-mole is given by Professor Wood-Jones:

Notoryctes is an inhabitant of the sandy and more arid parts of the country, and, owing to the nature of the soil in which it lives, is apparently not so completely a subterranean animal as are the true moles. The burrows which it makes in search of food are not permanent like the tunnels which are left by the European mole, and a portion of its time seems to be spent in furrowing the surface sand. It is, however, probable that it constructs deep permanent burrows in which the female lives and produces her young.

The Marsupial mole . . . may be said to be like the [placental] moles in its feverish restlessness. It evinces the most remarkable nervous activity. It makes endless tours around the confines of its cage, each peregrination being undertaken with characteristic energy and haste. It will search with feverish activity in each corner of its box, and regularly in each of the four corners turn a complete somersault in its enterprises. Suddenly it will discover something edible; the meal is accomplished with a maximum of speed; the performance is repeated and, in the case of a captive specimen I have observed, a handful of earthworms will be noisily accounted for in a remarkably

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short time. The meal having been ingested at top speed, the animal will again start upon its rapid tour; but it has proceeded maybe no more than a foot or two when, as suddenly as it awoke to activity, it is fast asleep. Even its sleep seems hurried. It breathes rapidly. It awakes with a start and is off again. It does not evince fear, nor resent handling, in the least, and when held in the hand will take a considerable quantity of milk at a great pace, and then on a sudden fall asleep again. In all its activities it carries its extraordinary stump of a tail erect in a manner singularly reminiscent of its lizard companion of the Centre [Central South Australia]—*Nephrurus asper*. Its gait is a rapid shuffling, the movements of its body strangely fluid and sinuous, so that when held lightly in the hand it seems almost to flow between the fingers. It is said that when moving on the surface of the ground the tail is “adpressed and used as a fulcrum”; but this is an observation I am unable to corroborate. Nor am I in agreement with those who suppose that “fear has a good deal to do with their dying so quickly in captivity.” It is true that their life seems to be carried on at such a high pitch that they appear as “very nervous little animals”; but I suspect that their active metabolism comes to an end rather through lack of food than from fright. Apparently they need an extraordinary amount of food when active; but possibly when inactive they can sustain prolonged fasts. They seem to be animals which live either at fever pitch or to remain almost wholly quiescent as season and circumstances demand. Of its breeding habits nothing is known, and the only embryo that I have succeeded in obtaining was the solitary occupant of the pouch.

CHAPTER XI

ORDINARY MAMMALS

By far the greater number of mammals, both living and fossil, belong to the subclass technically known as the placentals or monodelphians. For our purpose we shall simply call them ordinary mammals; and, so far as their anatomy is concerned, we shall only repeat that the young ones, before birth, are attached to the mother by a special organ called the placenta, which nourishes them during a relatively long process of growth within the safe protection of the mother's body. To this group belong all our domestic mammals, nearly all the wild kinds with which we are most familiar, and, indeed, man himself.

Because these mammals are so much better known than the egg layers and pouch bearers and because there are so many more of them, we shall not attempt to describe them in detail, but shall content ourselves with a rapid survey of some of the more noteworthy. How impossible it would be to do more than this will be realized when it is recalled that naturalists now recognize nearly 18,000 different species and subspecies of placental mammals, of which about 12,500 are alive today.

When we survey placental mammals as a whole we find, in the first place, that the great group is divided into many subgroups, or orders, the exact number of which varies somewhat according to the opinions of individual writers. The classification in this book places the number of orders at twenty-four.

It must not be supposed that these orders are equal, each to the other, in the distinctiveness of their structures or in

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the number of different kinds of animals that they contain. Some orders, like the bats, the whales, and the seacows, are so distinctive in structure that any of their members can be recognized at sight and no zoologist ever disputes their standing. Others, on the contrary, like the hares and the rodents, are so nearly alike that there is some controversy as to whether they are to be regarded as two orders or as only one. In the number of different kinds of mammals that go to make up each order there is a still greater variation. On the one hand, we find among living mammals some orders, such as the aard-varks, the pangolins, the flying lemurs, and the seacows, that contain from one to a dozen sorts only; while, on the other hand, there are a few orders, such as the bats, carnivores, and rodents, whose membership, in species and subspecies, runs well beyond the thousand mark.

No less variable is the distribution of the orders in both time and space. Some orders died out long ago and left no descendants. Others, like those made up of the hoofed mammals, are well represented by living kinds, but were much more flourishing and diversified in the past. Finally such groups as the bats and rodents appear to have more representatives now than ever before. As to present distribution, some orders—like the whales, bats, carnivores, and rodents—are world-wide in range. Other orders are distributed now much less extensively than they used to be; for instance, the elephants, which once ranged over all the continents except Australia, now live only in Africa and tropical Asia. Still other orders, like the aard-varks of Africa and the flying-lemurs of the Malay region, exist in limited areas only.

The history of each different order shows a course of growth leading up to a period in which the distinguishing characters are most perfectly developed, the number of representatives is greatest, and the geographical range widest. This period is or has been followed by one of overdevelopment, decrease in number of kinds, and re-



A mandrill now living in the National Zoological Park. No other known mammal has a skin so brightly colored as has this species of African baboon

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striction of range, which has led in some orders to partial or complete extinction. This kind of race history is not peculiar to mammals; it is known to occur in every group of animals whose past is chronicled in the fossil record completely enough to be intelligently read, and it is strikingly analogous to the life course of individuals and to the rise and fall of human civilizations. Some of the existing orders, like the bats, rodents, and primates, appear to be at or near their full flowering season now; others, like the hoofed mammals, seem to have been most numerous and diversified during Oligocene and Miocene times. At the beginning of the present geologic period, they were already much reduced in number of kinds—clear evidence that the process of extinction in which man is now actively aiding is a natural one. In South America we find the remains of large mammals belonging to a very peculiar group called the Notungulata or “south hoofed-mammals,” all of which are now extinct. The group can be traced all the way from Eocene to Pleistocene time, and the epoch of its greatest abundance was apparently the Pliocene. Other orders, such as those known to paleontologists as the Ganodonta, Tillodontia, and Amblypoda, ran their whole course, so far as the record has yet been read, in the Eocene epoch. We have gone into so much detail on this subject for the purpose of emphasizing the fact that all groups of animals, like all individual animals and all human societies and institutions, go through a natural course of growth, maturity, senility, and death.

SHREWS, MOLES, AND THEIR ALLIES: INSECTIVORA

The insectivores are small ground-living or sometimes tree-living placental mammals whose food consists chiefly of insects. This food, before being swallowed, is finely chopped by broad-crowned cheek teeth whose surface bears a complicated set of piercing points and cutting blades. Similar food habits and similar teeth are found

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among the bats, but these animals are at once distinguishable from the insectivores by their wings. Some other placental mammals, such as anteaters, aard-varks, and pangolins, subsist on insects, but they differ widely from the insectivores in having simple, flat-surfaced teeth or no teeth at all: instead of chopping their food they either mash it or swallow it whole. Mice and other rodents often eat insects; but the teeth of these mammals are built for gnawing and grinding instead of for chopping, and, with them, the insect-eating habit is only incidental and not characteristic of the group as a whole. With the insectivores the case is very different: if suddenly cut off from its supply of insect food the race of insectivores, with very few exceptions, would perish.

Mostly small in size and inconspicuous in appearance, the insectivores pass their lives searching for food in rotten wood, under fallen leaves, and among the roots of trees and other vegetation. In general, therefore, they are inhabitants of forests and thickets, though some of the burrowing kinds—the moles (see Plate 84, page 216)—which have changed their food from insects to earthworms, go far out on plains and prairies. Along with such uniform habits has gone a rather uniform bodily appearance; and most of the insectivores can be recognized by their mouselike form coupled with dense, velvety fur, very small eyes, and a slender, mobile snout projecting in front of the upper teeth. In size they range from the smallest mammals known—shrews scarcely more than an inch and a half in length, not including the tail—up to the relatively gigantic, opossumlike solenodons of Cuba and Haiti, the “gymnuras” of the Malay region, and, largest of all, the spiny tenrecs of Madagascar, heavily built animals about sixteen inches long.

Though most insectivores are mouselike or ratlike in general form some of them have a very different appearance. In the Old World we find the familiar hedgehogs, stockily built creatures densely covered with spines and

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able to roll themselves into prickly balls in defiance of carnivorous enemies. In the rivers of western Africa there is an insectivore that has become fully adapted to aquatic life: its tail is flattened from side to side, even more so than is that of our common muskrat. In Africa, also—but in the more open country to the south and southeast—there is another very peculiar type of insectivore; its tail and hind legs are elongated, and the animal progresses by vigorous bounds like a miniature kangaroo (see Plate 84, page 216). Out on the island of Madagascar we meet with insectivores that resemble hedgehogs in their possession of a prickly body covering; but the structure of their skulls and teeth shows that they are related not to their prickly hedgehog neighbors on the African mainland, but to the coarse-haired solenodons of the Greater Antilles. This extraordinary relationship seems to point to the conclusion that both the tenrecs, as the Madagascar animals are called, and the Antillean solenodons belong to an exceedingly ancient group of insectivores which had a world-wide distribution at a time so remote that there was continuous land between the West Indies and Madagascar, either by way of North America, Asia, and Africa or by way of land lying directly between South America and Africa.

Popularly, the insectivores may not seem to be of much interest. To the zoologist, however, they are of great importance, for two reasons. In the first place they are the only placental mammals now living that have left a fossil record extending back into the Age of Reptiles. Astonishing though it may seem, this means that unless the records deceive us insectivores not very different from some of those existing today were already on earth at a time so remote that not a single one of the other common types of placentals, as we are now familiar with them, had yet taken form. In the second place the insectivores illustrate more perfectly than any other known mammals the simple type of bodily structure from which it seems prob-

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able that a process of slow racial change could bring into being all the many and varied kinds of placentals that have ever existed, kinds as different as the bat, cow, elephant, cat, whale, and man.

About 1,000 kinds of insectivores are now known. Most of these belong to the present age, but at least 120 species have been described from fossil remains. Were these animals not so small that their bones are easily overlooked, the number of fossil species discovered would undoubtedly be much greater.

FLYING-LEMURS: GALEOPTERA

Nearly related to the insectivores are the flying-lemurs (Plate 105), of the Malay region. They are arboreal and have bodies about a foot in length covered with fine, silky fur delicately mottled with dull grays and browns, so that they resemble patches of lichens on the large branches of trees, where they sleep during the day. A parachute membrane extends along the side of the body between the fore and hind legs, and from the hind legs to the tip of the tail. By means of this membrane the little animals make long, gliding jumps from tree to tree as they search for their food or flee from their enemies in the thick tropical forests. In this one feature the flying-lemurs resemble the flying squirrels; but otherwise they are very different, having a bluntly rounded snout and curious, comb-shaped front teeth. Though related to the insectivores in their general structure, they eat only fruit and leaves. They are nocturnal in habit, like our familiar flying squirrels. No fossil relatives of the flying-lemurs have yet been found.

BATS: CHIROPTERA

A bat is the only mammal that has wings. It can be distinguished from a bird by the fact that its wings are made of thin skin and not of feathers (see Plate 85, page 217). Bats, however, are not the only mammals that can move through the air. Several other kinds, such as the



Flying-lemur, which lives in trees and planes from limb to limb. About the size of a large squirrel. Probably its nearest living relatives are the insectivores. Specimen in the National Museum



Pine marten carrying squirrel. Both these animals are expert tree climbers. Though much alike in form they are not related. Group in the National Museum

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flying-lemurs and flying squirrels, can make astonishingly long, gliding jumps, skimming obliquely downward by means of parachute membranes stretched along the sides of their bodies between the fore and hind legs. But only bats can propel themselves upward by flapping the fore limbs as we see the birds doing now and as flying reptiles called pterodactyls used to do in those remote times when great tracts of the interior of North America were covered by a shallow sea. Though the wings of birds and those of bats work in the same way, they are constructed on different plans. In a bird's wing the fingers are rudimentary, and the flying surface is made by the feathers that grow out from the skin. In a bat's wing the fingers are enormously long; and the flying surface is formed by a continuous membrane of skin that lies between them, between the fifth finger and the legs and sides of the body, and between the two legs, connecting these parts along their entire length. When a bat extends its arms, fingers, and legs, this membrane becomes stretched like the cloth of an umbrella, thus forming a perfect wing.

Bats live practically everywhere that insects can be found to eat and that trees or caves can be found to roost in. Most of them hunt at night and sleep during the day, hanging upside down in dark places. Insects are their usual food; but a few species of bats are known to capture fish, small frogs, lizards, and even small birds; and in the warmer parts of America and the Old World there are many sorts that have learned to subsist entirely on fruit. Among the fruit eaters are the Old World "flying-foxes," which include the largest bats known, their wing spread, from tip to tip, measuring more than five feet. Years ago these flying-foxes were not infrequently seen in collections of live animals in this country, but their importation to the United States is now forbidden because of the possible danger that the animals will escape and establish themselves in the fruit-growing regions of the South and Southwest.

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Among the many bats of tropical America there are three kinds called vampires, because they subsist entirely on blood. This food is so easily assimilated that no stomach is needed; therefore the animal's digestive apparatus consists of a simple tube uniform in caliber from end to end. Contrary to popular supposition the vampires are not large bats, and they are quite incapable of "sucking" blood. Their length, including head and body, is about three and a half inches, and their manner of feeding is unlike that of any other known mammal. The teeth (Fig. 22) are so sharp-edged that they inflict a wound like the scratch of a safety-razor blade, which is scarcely

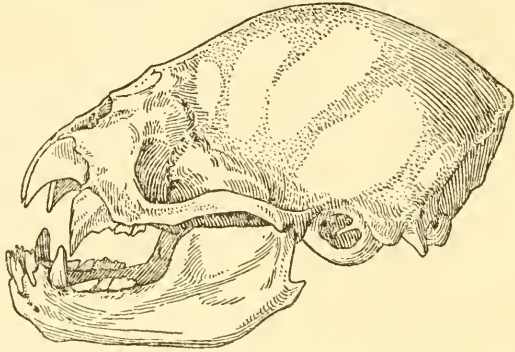


FIG. 22. Skull of vampire bat, showing the razor-sharp teeth. Enlarged about three diameters

ly felt but which produces copious bleeding. The bat, therefore, does not awaken its sleeping victim, and, after inflicting its small wound, it has merely to drink the flowing blood. The direct harm done by the bat is slight; but the little wounds, especially if in considerable number, often become infected and thus cause serious injury to horses and cattle.

Many bats are provided with picturesque outgrowths of skin on the muzzle and face, some of which may be seen in Figure 23. Except that they are a joy to the eye of the beholder, these "noseleaves" serve no known purpose. Relatively few bats possess them, and there is nothing to show that the ornamented kinds are any more successful in their life work than the unadorned.

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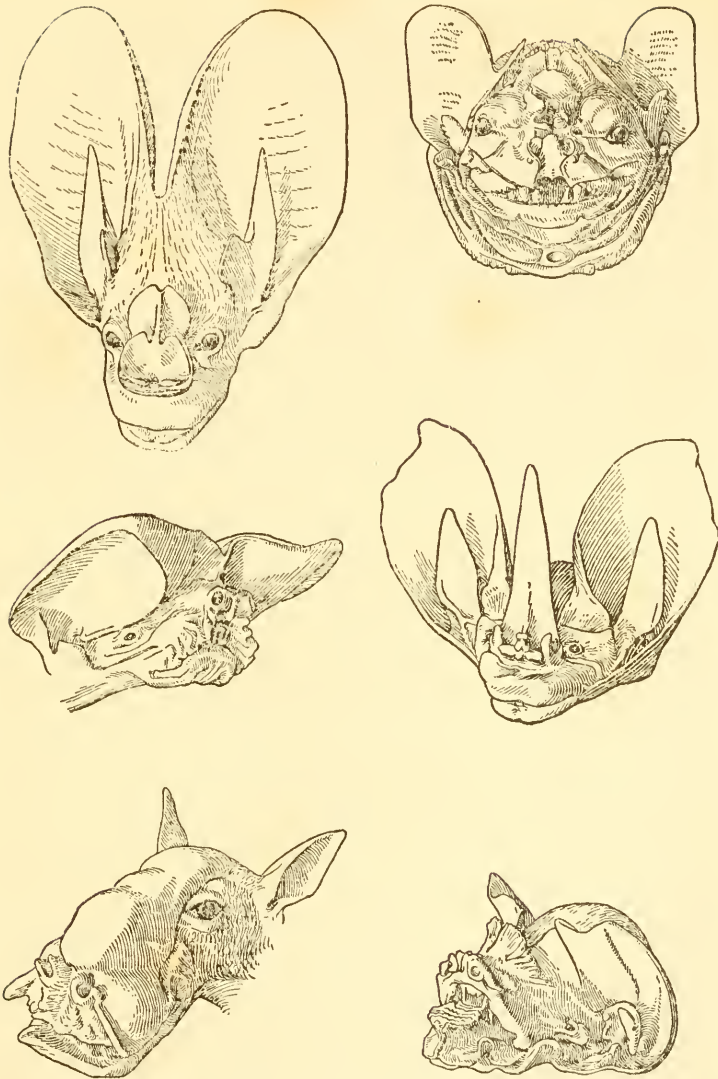


FIG. 23. Heads of bats showing different kinds of skin ornamentation, no one of which seems to be more "useful" than another. Drawn from casts in the National Museum

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Bats are popularly supposed to act as carriers of bedbugs from house to house, an idea for which there is no foundation of fact. Flat-bodied insects of several kinds live as parasites on bats, but there seems to be no positive record that the domestic bedbug is numbered among them. If this insect is ever carried by bats, therefore, it must happen so infrequently as to furnish no ground for the common belief.

About 1,600 species of living bats are known, and about 100 fossil species extend the history of the order back to the Eocene epoch. But up to the present time no fossil has been found that throws any light on the way in which wings have been developed out of climbing feet; that is to say, the earliest known bats were as fully equipped for flying as the ordinary bat of today.

PRIMITIVE CARNIVORES: CREODONTA

In both North America and the northern part of the Old World the rocks of Paleocene, Eocene, and Oligocene (or "early" Miocene) age contain many fossil bones of primitive carnivores—mammals with characteristics of the insectivores on the one hand, but perhaps more especially of the present-day carnivores on the other. These creatures were all large enough to have been efficient killers, and among their number was the giant *Andrewsarchus* of Mongolia, the largest known terrestrial carnivore. Its fossil skull is about three feet long, and its bulk must have been at least half again as great as that of the Kadiak bear, the largest living carnivore. The idea that *Andrewsarchus* fearlessly slaughtered and gluttonously devoured the correspondingly gigantic rhinoceroslike creatures whose bones are found in the same rocks tempts the imagination by its gory picturesqueness; but the animal was probably forced by its great bulk to be a relatively peaceful, carrion-eating member of creodont society. And, indeed, the presence of small brains and rather poorly developed flesh-eating teeth makes it seem possible that



Fur seals of the Pribilof Islands. Group formerly in the National Museum



Spider monkey, of South America,
which uses the tail almost as a
fifth arm

One of the lemurs of Madagascar.
The lemurs are the most primitive
of living primates

Specimens in the National Museum

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the creodonts were on the whole less aggressive than the true carnivorous mammals that succeeded them.

The remains of about a hundred species of creodonts have been discovered, all of them long ago extinct.

THE TRUE FLESH EATERS: CARNIVORA

The carnivores might be roughly described as enlarged insectivores made over for preying on their fellow mammals. While the insectivores, in conformity with the food that they seek and with the manner of living that they follow, are mostly small, the carnivores, for these same reasons, are large enough to kill the mammals and birds on which they live. Consequently we find among them a graded series of sizes, beginning with the mouse-eating weasel and gradually increasing up to the deer-killing puma and the zebra-killing lion. Rather strangely, the largest of living carnivores, the bears, are not exclusively, or even generally, flesh eaters. Their food consists in great part of berries, roots, fish, and even insects; and their teeth do not have the highly developed cutting edges that we find in the teeth of most carnivores. In the warmer parts of America and also in the Malay region there are tree-living carnivores that feed almost exclusively on fruit. Their teeth are blunt-pointed for mashing fruit pulp, but the arrangement of these points is the same that we find in their strictly flesh-eating relatives.

Among the well-known carnivores are included our domestic dog and cat. The dog has been associated with man from time immemorial and has accompanied him on all his wanderings. No one knows what wild creature was the ancestor of the domestic dog, but the structure of the dog's teeth shows that this ancestor must have been a wolflike animal, probably most similar to certain wolves now living in India and in western China. It has been supposed by some writers that the mixed blood of several remote wild ancestors—such as the wolf, jackal, coyote, fox, and others—is now flowing in the veins of our

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domestic dogs; but it seems to us that the evidence of such mixture, beyond the occasional infusion of a strain from a timber wolf, is entirely unconvincing. More probably all the domestic breeds of dog have been produced from the descendants of an originally uniform stock by the process of human selection, unconscious at first, and deliberate later. A noteworthy fact in this connection is that the dogs of the Peruvian Incas had teeth like those of dogs native to regions farther north, though no wild South American member of the dog tribe had teeth of this kind. The obvious conclusion is that the domestic dogs of the Incas were brought from the north and were not developed in Peru by taming an animal found wild there.

The ancestry of our house cat appears to be less obscure, and it seems highly probable that this domestic animal came from a cat still found wild and widely distributed in Africa, with markings similar to those of the striped tabby. But, very curiously, the blotched tabby marking, frequently seen in domestic cats and rarely if ever blended with the striped pattern, has not yet been found in any wild member of the feline tribe.

Carnivores in general are too well known to require any detailed enumeration here. Their principal groups, or families, in addition to the bears, dogs, and cats, are as follows: The raccoon family (the raccoons, coatis, and the kinkajou of North and South America, and the panda of southern Asia); the bassarisk family ("ring-tailed cats" or "civet cats" of Mexico and the southwestern United States); the weasel family, including, besides the weasels, the minks, otters, martens (Plate 106), fishers, wolverines, skunks, badgers, and others less well known; the civet family, confined to the Old World, and including the civets, genets, mongooses, and others; the family to which *Cryptoprocta* belongs, confined to Madagascar; the hyena family, now restricted to Africa and southern Asia but formerly ranging to England and perhaps to the western

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United States; and the aard-wolf family, African creatures standing near in classification to the hyenas but with small, weak teeth suited to a diet of soft food instead of the carrion and bone marrow on which their large relatives subsist.

Most of these families are also represented by extinct species and genera, some of them, as the dogs and weasels, going back as far as the upper Eocene. Among the most remarkable of the extinct carnivores are the members of the group known as the saber-toothed cats. These animals were of moderately large size, the largest and most recent of them, which are found in deposits of late Pleistocene age, being about the size of our puma. Their chief peculiarity lay in their enormously elongated, saber-shaped upper canine teeth, which projected downward, far below the chin, and may have somewhat interfered with the eating of large mouthfuls of food. It has therefore been suggested that the long canines might have been used for gashing the flesh of the saber-tooth's prey and provoking a free flow of highly nutritious blood, a method of feeding that now finds its analogies in the habits of the vampire bats and of those African tribes of negroes who bleed their cattle as well as milk them. A critical study of the dental mechanism of these great cats, however, gives little ground for such a supposition. It seems more reasonable to infer that the large sabers were used in conjunction with the terrible claws of the fore feet to obtain a firm grasp on the prey, while the powerful hind feet clawed out the entrails of the victim (see Plate 76, page 193). Of the more than 2,200 species of true carnivores known, about 700 are extinct.

SEALS AND THEIR RELATIVES: PINNIPEDIA

The seals and their relatives are so nearly related to the true carnivores that by many authorities they are not regarded as forming a distinct order. Their main peculiarity is that their feet have been so modified to serve

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as fins that they are of little or no use for walking on land. Next to the whales and seacows the pinnipeds are the mammals most completely fitted for aquatic life. Among the most conspicuous and interesting kinds may be mentioned the fur seals of Bering Sea (Plate 107), the Arctic walrus, with its long, downward-projecting ivory tusks (see Plate 86, page 220), the huge, southern sea-elephants, said to weigh several tons, the sea-lions of our Pacific coast and of every properly equipped circus ring, and the widely distributed hair seals. All pinnipeds procure their food—fish, squids, crabs, and shellfish—in the water; but, unlike the whales and seacows, they must come out on land or on ice to breed. Altogether about 100 kinds are known, slightly more than half of them now living. At present these animals occur in all the oceans from the northern ice edge to the ice of the southern polar continent; but their distribution, depending as it does on available breeding grounds, is not continuous, and there are wide stretches where they are not found. Although they are characteristically marine animals, one pinniped, the seal of Lake Baikal in central Siberia, is landlocked in fresh water.

MANLIKE MAMMALS: PRIMATES

In our chapter "Shop Talk" we explained why the primates, that is to say, the group of mammals that includes the lemurs, monkeys, apes, and men, are no longer regarded as the "highest" group of all, as the culminating point of mammalian development. The subject is so important that we wish to return to it here.

For zoologists there cannot properly be any one "culminating point" in a developmental process that is now usually conceived of as moving along many lines toward the perfecting of many different types of structure, each of which enables its possessor to do one kind of work particularly well, as, for instance, the flying of bats, the running of horses, the swimming of whales. Into the



Horse-tailed monkeys, from Africa. Group in the National Museum



Gorilla, the largest of the primates. Old males probably exceed 450 pounds in weight and six feet in height. Specimen in the National Museum

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discussion of these results the idea of "higher and lower" does not profitably enter, because there is no common term of comparison between the different kinds of results. If the idea of "greater and less efficiency" were to be substituted for that of "higher and lower" nothing would really be gained, because every animal is efficient in its own particular way. The only standard left for us therefore, is the degree of change that has been undergone by the members of the different groups during the course of their development from the simplest and most ancient mammalian structure to their most perfect state. Judged by this zoological criterion, the primates have not, on the whole, gone very far in altering their structure from that which the first placental mammals are supposed to have had.

From one popular human point of view the fact that primate progress has been largely along the line of brain development makes this group of mammals seem particularly admirable. But, if judged according to another popular standard, "the greatest good to the greatest number," the primates would appear far from preeminent. The rodents, for instance, surpass them by more than sevenfold in the number of species that have been evolved, and exceed them incalculably in the number of individuals that can exist in the world at one time without detriment to each other.

When we put aside these necessarily controversial ideas and return to the zoological point of view it seems possible to agree that the primates have, on the whole, undergone more modification in structure than either the insectivores, the bats, or the carnivores, and less modification than the rodents, ungulates, edentates, and whales.

The least specialized of the primates are the lemurs (Plate 108)—nocturnal, soft-furred, large-eyed creatures, many of them with long, pointed muzzles and catlike general build, though with clasping hands and feet. Most

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of the known lemurs are found on the island of Madagascar, but there are some others on the continent of Africa and on the mainland and islands of southern Asia. A few of them are heavy-bodied and short-limbed sloth-like tree clingers; while in the Malay region there is a very peculiar type called *Tarsius*, with huge eyes, lengthened hind legs and padded feet, a combination of structures that enables these little nocturnal animals to leap and cling among the branches with the agility of tree frogs. Fossil remains of lemurs show that the group was once very widely distributed, its range having extended as far away from the Tropics as Europe and the western United States.

Coming to the monkeys, we find that these well-known animals are abundant in both species and individuals throughout the wooded tropical regions of both hemispheres. Though as a group monkeys are definitely tropical, there are a few kinds that inhabit the cooler parts of southern Asia, particularly Japan and western China.

Monkeys present a surprising variety of size, form, color, and marking. In size they range from the little marmosets of South America, no bigger than squirrels, up to African baboons probably weighing not less than a hundred pounds. In form they may be squirrel-like or doglike; the tail may be any length, from much longer than the body down to a mere stub; it may serve as a balance to aid the animal in running and jumping among the tree tops; in some of the South American kinds (Plate 108, right) it has a prehensile tip that makes it practically a fifth arm; and in a group peculiar to Africa it is so long-haired as to suggest the tail of a horse (Plate 109). Strange though it may seem, however, the most skillful climbers of all the monkeys, the gibbons of the Malay region (see Plate 70, page 168), have no external tail whatever, yet their swinging and jumping from branch to branch and from tree to tree is almost birdlike in its agility. In color monkeys range from black to white, with every inter-

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mediate shade of brown, usually yellowish faintly tinged with red or sometimes with green. In two peculiarities of ornamentation—namely, the coloring, often brilliant, of the bare skin of the face and the buttocks, and the variety of head patterns made from contrasted areas of long and short hair and of patches of strikingly different colors—the primates in general and the monkeys in particular show more individualities among their different kinds than is to be found in any other group of mammals. They also present the best examples known among mammals of striking color differences between males and females. Bright skin colors are shown on Plate 104, a few examples of head ornamentation in Figure 24, and an example of different coloring in the two sexes on Plate 70 (see page 168).

The primates known as great apes or anthropoid (manlike) apes are just now arousing particular interest. There are three main types of these animals: The gorillas (Plate 110) and the chimpanzees of the African equatorial forests, and the orangs of Borneo and Sumatra. The gibbons are commonly reckoned among the anthropoids, but we believe this classification to be a mistake. They belong more properly in a special group of their own. Many supposed different kinds of gorillas, chimpanzees, and orangs have been described by zoologists, but the most recent and careful investigations show that there are probably not more than two orangs, two gorillas, and perhaps three or four chimpanzees.

During the past twenty years, the great apes and the monkeys have been used more and more as subjects of psychological study. In this way there is being built up a mass of information that almost amounts to a new department of knowledge—an accurately observed and recorded comparative psychology of man and his nearest relatives in the animal kingdom. The far-reaching results that this work may have on generally accepted ideas about the human mind and human behavior can

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now be only guessed at. Two of these results that already seem to be rather well established may be mentioned. First, it has been shown by carefully planned psycho-

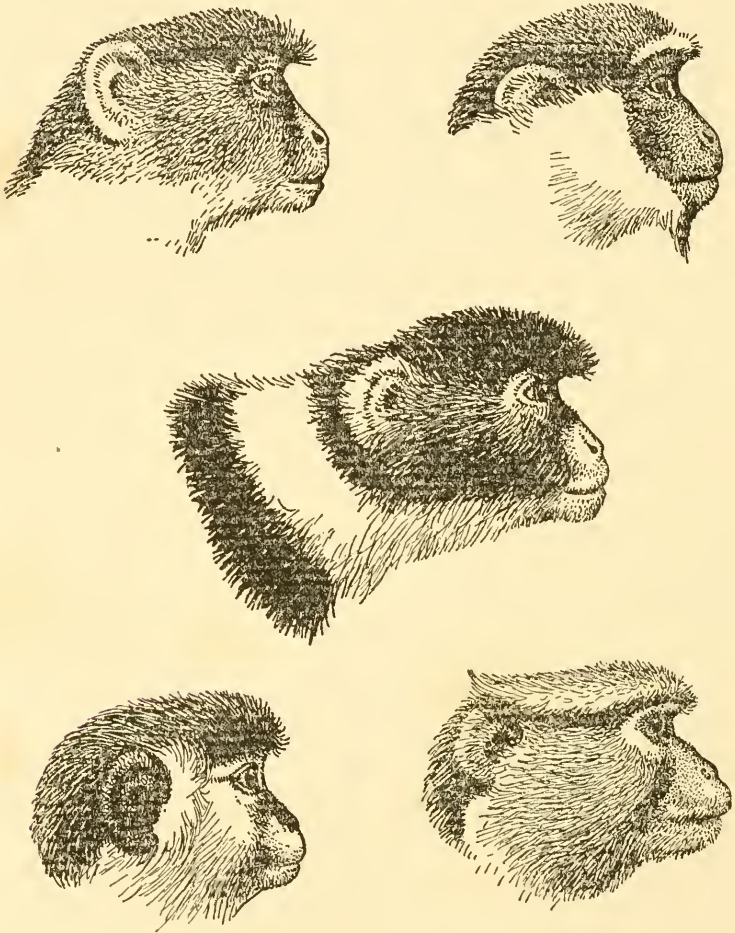
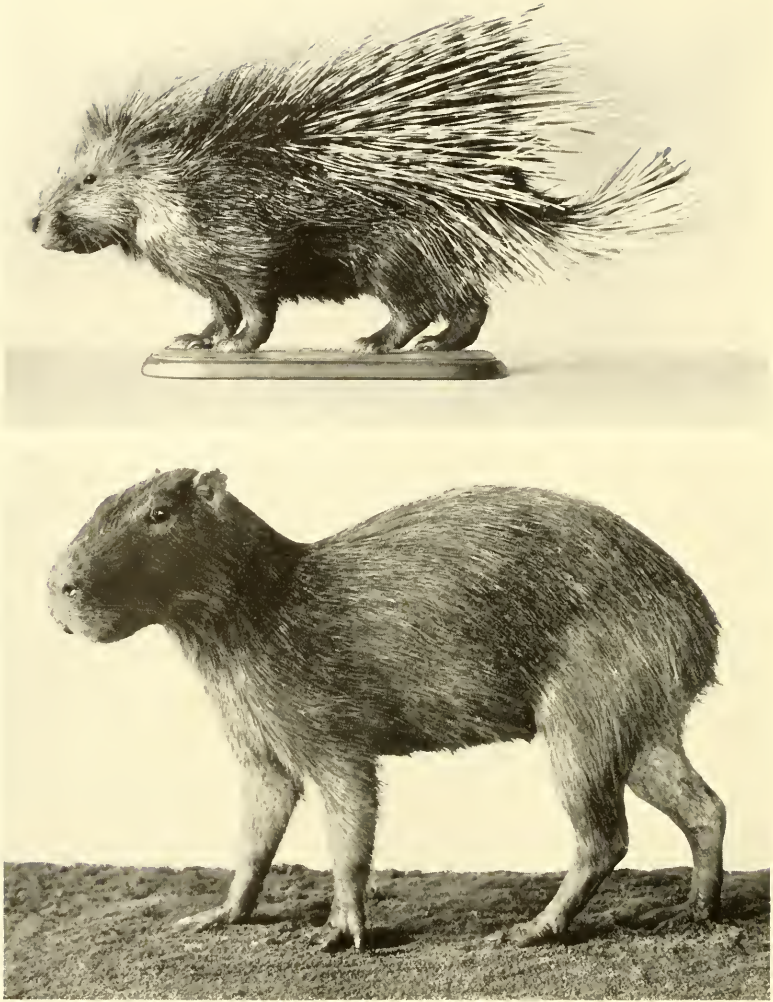


FIG. 24. Heads of African monkeys showing the distinctive color pattern assumed by the hair in each of several species. No one pattern can be said to be more "useful" than another.
After Elliot



Lemming, a rodent that periodically invades Scandinavian fields. European harvest mice in the background, climbing among wheat stems. The harvest mouse is one of the smallest rodents known. Group in the National Museum



Two large rodents

Upper: African porcupine. Lower: Capybara, the largest of living rodents. Some individuals weigh as much as a hundred pounds. The capybara is now confined to tropical America, though it once had near relatives in the southern United States. Specimens in the National Museum

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logical tests that the processes of acquiring and applying knowledge are alike in the great apes and in man. The differences are mostly differences of degree and not of kind. Apes learn less than men and make less use of what they learn; but the way in which they do both is the same as ours. Hence it seems probable that the gulf popularly supposed to separate the human intellect from the minds of all "lower" animals does not really exist. Next, it is becoming increasingly evident that some phases of human antisocial behavior can be best understood when they are regarded as traits that are common to all primates and harmless to those members of the group that have never established such complicated systems of community life as we have.

That man is a primate and that he is therefore genuinely related to all other primates from marmoset to gorilla are two propositions about whose truth most zoologists are agreed. But when it comes to the questions of tracing the human family line back into the past and determining the position of that line among the lines of other living members of the order, it would be only a slight exaggeration to say that every zoologist is always ready to argue hotly with all his fellows. The main reason for this happily stimulating condition is that no one has yet discovered fossils that can settle the question. Two sets of fossil fragments, known respectively as the "Java" man (*Pithecanthropus*) and the "Piltdown" (England) man (*Eoanthropus*),¹ about which there has been built a huge structure of controversy, are so lacking in the parts essential to classification that each one can be made to fit admirably into several different and conflicting schemes of relationship. And these fossils are the only ones that can now (1931) be seriously regarded as having pertained to creatures that combined the anatomical structure of man with the anatomical structure distinctive of non-human primates. All known primate fossils complete

¹ These fossils are fully discussed and illustrated in Volume 7 of this Series.

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enough and well-enough preserved to show their true nature are definitely either man or ape.

Three main ideas as to the probable direction of man's ancestral line have been most seriously discussed. They are: (1) That this line runs, at a comparatively recent time, geologically speaking, into the family to which the living great apes belong; (2) that it runs back to a very ancient and now unknown primate stock from which sprang both the human and great ape lines; and (3) that it has always been distinct from the line that led to the great apes and that it goes back to early lemurs that gave rise not only to man but to the long-legged, tree-jumping *Tarsius*.

To us it appears that the known evidence in favor of each one of these ideas is inconclusive, and that it ought to be frankly recognized as inconclusive until paleontologists succeed in discovering some fossil animal having a structure unquestionably intermediate between man and other primates in several of those skeletal parts that are of first importance to classification. Such parts in this instance would be the foot, the pelvis, and the base of the skull, all of which are missing from the finds that have been most written about. Intermediateness, no matter how perfect, in the form of less important features, like the skullcap, the thigh bone, the jaw, or the molar teeth, will never do more than demonstrate the past existence of an animal that had these particular parts of its anatomy intermediate between the same parts of man and of some other primate. Fossils possessing such characters must always arouse interest; but we can not too strongly emphasize the fact that intermediate parts of this less essential kind might easily occur in extinct creatures, which, if the rest of their anatomy were known, would at once be seen to have been definitely and unquestionably apes, with a total structure quite unlike that of man and quite incapable of throwing any direct light on the problem of man's origin.

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RODENTS, OR TRUE GNAWING MAMMALS: RODENTIA

Rodents are distinguished from other mammals chiefly by the character and arrangement of their teeth and of the muscles that work the chewing machine. A pair of front teeth in the upper jaw and a corresponding pair in the lower jaw, covered with hard enamel on their front surfaces, act as chisels for cutting wood, nutshells, or any kind of hard or soft material that may serve as food. These gnawing teeth grow continuously throughout the animal's life and maintain their uniform length by wearing off at the tips in the course of daily use. Should one tooth become diseased or broken, the tooth in the opposite jaw against which it should work goes on growing unchecked, and may come to project, hornlike and useless, far out of the mouth, the tip curving backward and often penetrating into the skull. In rare instances something causes all four of the gnawing teeth to go wild. Behind the sharp-edged gnawing teeth there is a wide toothless space followed by the flat-topped grinders, usually three or four in number on each side both above and below, that is, twelve or sixteen in all. Because the lower jaw has to be thrown forward for gnawing and drawn backward for grinding, the muscles that work it have a peculiar arrangement not found in other mammals.

The rodents surpass every other order of placental mammals in number of species, in number of individuals, in variety of bodily form and of external appearance, in contrast in size between the smallest and largest, and in diversity of mode of life. In the wideness of its distribution the order is only exceeded by the cetaceans, whose range includes all the seas of the globe; but on land it easily surpasses its nearest competitor, the bats (Chiroptera), because of its ability to exist far beyond the northern limit of forests.

Rodents, with their peculiarly efficient teeth and with a bodily structure that is easily adaptable to many modes

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of living, are able to make use of more of the opportunities that nature offers to backboned animals than are any other mammals. While most of them live on or near the surface of the earth, some kinds pass their entire existence in tree tops, and others are as truly subterranean as the insectivorous moles. Many kinds are highly specialized for life in marshes and streams, while others, like our well-known kangaroo rats and pocket mice, may become so perfectly adapted to deserts that water is not necessary to them, even as drink. Their mode of progression varies from ordinary walking and running to jumping as perfect as that of a kangaroo, or climbing almost equal to that of a monkey; and from expert swimming and diving in the water to sturdy plowing through the earth and buoyant planing through the air. No rodent is known to be or to have been adapted to life in salt water and to feeding on seaweed; but wherever green vegetation grows on land or in fresh water, except on remote islands, some rodent is there to make use of it. Nor is the food of rodents exclusively vegetable. Some kinds are fish eaters; others subsist on grubs and soft insects; and still others, as we know from our experience with house rats and house mice, appreciate everything good to eat.

Most rodents are rather small animals ranging in size from a rat to a woodchuck. Some of them, like the European harvest mouse (Plate 111), are small enough to climb freely among stalks of wheat, while the largest now living, the South American capybara (Plate 112, lower), may reach a weight of 100 pounds. This size was exceeded by the extinct *Eumegamys*, also of South America.

Rodents surpass all other orders of mammals in the diversity of things they can do, in the extent of the territory that they occupy, in the variety of local conditions under which they can flourish, in the number of strikingly contrasted species that they have developed,



Restoration of *Epigaulus hatcheri*, an extinct rodent with horns. It inhabited the Great Plains region soon after the completion of the pre-Badlands plain. It was larger than the pocket gopher and more completely adapted to burrowing



Representative lagomorphs

Upper: Pika, or little chief hare, which prefers rocky surroundings.

Lower: Common hare, which prefers flat country suited to running.

Specimens in the National Museum

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and in the numerical superiority that they are able to maintain over other mammals in most places where they occur. These are facts that seem to indicate that the general bodily structure of rodents is more perfectly adjusted than that of any other order of mammals to the physical conditions existing on the surface of the earth. Another peculiarity of rodents that may have materially contributed to their success is the fact that they alone among mammals other than man and the "little chief hare" have learned to store up in times of plenty supplies of food for use in times of need. As everyone knows, the food-storing habit is highly developed in many rodents. Outside of this group it is found in the curious "little chief hare" and in man; but we are unable to recall a truly comparable instance in any other mammal, though traces of the habit may be seen in some of the insectivores, notably in our common short-tailed shrew. Whether or not these elements of superiority mean that the rodents are destined eventually to become the dominant mammals of the world is an interesting subject for speculation. In thinking about it one significant fact should be remembered: namely, that while man is rapidly bringing toward the verge of extermination many members of every other order of mammals on which he has brought his destructive genius to bear, he has made no conspicuous progress against the rodents, but has rather tended to increase the number of individuals and to widen their range.

Among the best known rodents are the members of the squirrel tribe. These familiar animals are mostly tree dwellers, with long bushy tails that serve to balance the body in climbing and jumping. But some of them, like the chipmunks, prairie-dogs, marmots, and others, live both on and in the ground, while their not distant relatives, the pocket gophers, are root-eating burrowers of the most confirmed sort, often constructing extensive tunnels at a depth of ten or more feet, and rarely venturing out on the surface. Conspicuous color markings and

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bright colors are often seen in members of the squirrel tribe, especially among the tropical tree squirrels. Two of these brightly ornamented animals are shown in Plate 94 (see page 248). Their coloring represents the nearest approach among mammals to the parrot type of coloring among birds. In the flying squirrels a fold of skin extends out from each side of the body between the fore and hind legs. When the legs are held stiffly outstretched these folds of skin act as parachute membranes by means of which the animals can make astonishingly long, planing jumps from tree to tree. An African rodent called *Anomalurus*, resembling a large flying squirrel but not related to any member of the squirrel tribe, has a series of sharp-pointed horny plates on the underside of the tail near its base. These plates when pressed against the bark of a tree aid the animal in climbing in the same manner as do the stiffened feathers of a woodpecker's tail.

Not distantly related to the squirrels are the beavers, whose house-building activities are admired by everyone but whose much more astonishing feats of hydraulic engineering are little known. Beavers sometimes construct canals as much as 750 feet in length, 3 feet in depth, and from 3 to 5 feet in width, to afford facilities for floating their food supplies (consisting of sections of branches and tree trunks) from groves of aspens or other trees to the ponds in which their houses are built.

Other relatives of the squirrels are the pocket mice and kangaroo rats found everywhere in the arid portions of the western United States. Here they are enabled to exist without water to drink by a peculiar physiological process which transforms part of the food that they eat into water within their bodies. Like the pocket gophers these rodents have a pouch of skin in the cheek at each side of the mouth. The pouches are separate from the mouth and are used for carrying food, which is put in and taken out with the fore feet. The kangaroo rats

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are graceful jumpers; they have long hind legs, long tail, and silky fur (see Plate 93, page 245).

Better known than the squirrel tribe is the tribe of the rats and mice. Two members of this tribe, the house rat and the house mouse, are more familiar to civilized man than any other rodents. But no one not a zoologist can have any idea of the bewildering number of different kinds of rats, mice, and related rodents that exist in the world today. More than 3,000 different sorts of these animals have already been discovered, and the list goes on increasing year by year as specimens from new regions are brought together and studied. Many species of the rat and mouse family are notable for graceful form and attractive colors. The white-footed mice of North America and the wood mice of Europe, for instance, are slender, large-eared, long-tailed animals, with fine, silky fur. Their color above is brown, tinged, in different species, with red or yellow; below, it is pure white. Though not very nearly related to each other the white-footed mice and the wood mice are curiously alike in habits and in general appearance; and in their respective homes they are so abundant that they will probably be the first small mammals met with by the collector when he goes to the woods with his traps, as happened to Frank Bolles when he set his "cyclones" "at the North of Bearcamp Water" (see Chapter III). The richly furred American muskrat is another well-known member of this tribe. So also are the short-tailed, short-eared meadow mice or voles, many different species of which inhabit the Northern Hemisphere. Related to the muskrat and the meadow mice is the Scandinavian lemming (Plate III), about whose "migrations" many stories have been told.

This brings us to the subject of mouse and rat migrations, or plagues, as they are called. The Norwegian lemmings, for instance, often come down from the mountains in great numbers to the cultivated valleys, where they

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do not permanently live. The moving swarms of these animals hesitate at no obstacle. They plunge fearlessly into any body of water that may lie across their path, even when it is so wide that all must perish without reaching the opposite shore. This has given rise to the belief that the lemmings are guided in their course by a migratory instinct inherited from ancestors that formerly traveled in the same direction over land once dry but now submerged. Though this idea is a natural one, it is wrong. To understand what the wandering lemmings are really about we must first look at a peculiar characteristic of the rodents. Almost any species of these mammals may suddenly and mysteriously disappear from a particular place or may as suddenly and mysteriously increase to prodigious numbers. Every collector will sooner or later have the experience of finding a locality abounding in "signs" of small rodents but totally deserted by the animals themselves. Runways and tunnels may extend in every direction among the roots of trees and bushes and under dead leaves and dry grass, but traps set in them by the dozen and for many successive nights remain constantly empty. Though the runways are fresh and the tunnels show no tendency to cave in the animals that made them are no longer there. And to all appearances there is no lack of suitable food. But the entire population of small mammals has disappeared as if swept away by a plague. At other times the exact opposite occurs. Some rodent suddenly multiplies so excessively as to exhaust its local food supply. The animals must then either move or starve. How enormously a particular kind of rodent can multiply is well shown by the outbreak of house mice that occurred during the fall of 1926 and winter of 1927 in the region of Buena Vista Lake, near Bakersfield, Kern County, California. Mr. E. Raymond Hall visited the region in January, 1927, and wrote as follows of the conditions that he found there:



Dassie, or hyrax, many kinds of which inhabit Africa. The dassies, although only about the size of marmots, are more nearly related to the rhinoceroses than to any other living mammals. Specimen in the National Museum



Square-lipped rhinoceroses from Uganda, Africa. The birds on the animals' backs are searching for ticks. Collected in 1909 by the Smithsonian-African Expedition under the direction of Theodore Roosevelt. Group in the National Museum

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At the source [of the outbreak], the dry bed of Buena Vista Lake, the writer found as many as 17 mice per square yard over an area of many acres in extent in the kafir corn field. Computed from the counts made on the measured areas, one arrives at the startling number of 82,280 mice per acre. This gives 2,468 pounds of mice per acre, figuring that $33\frac{1}{3}$ house mice weigh one pound . . . In the invaded oil fields on the west side of the lake, poisoned wheat placed in yards about houses netted, at each house, in the morning, from 15 gallons to as much as 6 ordinary wheelbarrows full of dead house mice. Equal quantities were found at the oil derricks. In one barn on the Honolulu [Oil] Company's property, where grain was stored, approximately two tons of mice, according to reliable report, were killed in one day when the grain was sifted and moved. A series of four furrows surrounded this company's property, and in the second furrow back from the lake, where it paralleled the lake margin, an average of between 15 and 16 dead mice per linear foot was found on the third day after the furrow had been made. Others that had taken poisoned grain in the trench went some distance away from it and might be found dead beneath bushes or any other shelter. This trench was about five miles long and it was computed that one-half million mice had been killed by eating the grain placed in it. . . .

Grain bins that I saw had literally thousands swarming about in them; haystacks sheltered nearly as many; and the fields, since they had not been grazed by domestic stock, sheltered millions more. In one grain bin 20 feet square, that was two-thirds full of sacked barley, it was computed that 3,520 mice were in sight at one time. These were on the surface of the grain, on rafters, and on the pole plates. Many times this number unquestionably were out of sight in and among the sacks of grain. At night, on the highway that passes along the north side of Buena Vista Lake, the illumination from the headlights of one's car revealed hundreds of live mice at any given instant. . . . Truly, the number of mice was almost unbelievable, and one who has not seen this or a similar outbreak can scarcely comprehend the vast numbers that can occur in a given area of limited extent. Certainly the numbers were to be reckoned in tens, and possibly in hundreds, of millions.

Mr. Hall found that the mice had achieved their phenomenal increase among the rich grain fields of the drained portion of the lake bottom. When the food was exhausted they set out in every direction to search for a new supply. Exactly the same thing happens periodically to the lemmings in Norway. When abnormal

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multiplication takes place, usually at intervals of from three to five years, the animals are forced by threatened starvation to leave their mountain homes and come down to the valleys. This is not migration, which means an orderly seasonal movement from one place to another and then back again. The lemmings, driven by hunger, push blindly forward without sense of definite direction, and, in the end, all of those that reach the valleys perish there, even though they succeed in finding abundant food. They cannot live permanently away from the cooler climate of the mountains and they do not know how to return to the place of their birth.

Another notable group of rodents includes the jumping mice of North America, the jerboas of Asia and northern Africa, and the jumping hares of eastern and southern Africa. Among these animals the jumping habit and the structures that make it possible are carried to a perfection unknown elsewhere except among the kangaroos.

Passing over a few rodents that have no general interest we come to the great group of hystricoids, or porcupinelike animals. These are widely distributed over Africa, southern Asia, the forested part of North America and nearly all of South America. In structure they represent the most extreme and perfect working out of the rodent type. Most people are familiar with the sharp-quilled porcupine (Plate 112, upper); but few know that among the porcupine's relatives are to be numbered the soft-furred chinchilla, the South American capybara (the largest of living rodents), and the domesticated guinea-pig. Also akin to the porcupines are the large African cane-rats, the spiny-rats of the tropical American forests, and the tuco tucos of the South American pampas, small gopherlike burrowers. Apparently the porcupine group reached its greatest development in South America. During the long period when this continent was isolated from the rest of the world a multitude of porcupine relatives arose, flourished, declined,

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and disappeared, leaving their bones to tell the story. Among these creatures was the great *Eumegamys*, a veritable giant among its kind, quite possibly exceeding in size the largest of living pigs.

Many fossil rodents have been discovered in other parts of the world as well as in South America. They carry the history back to the early days of the Age of Mammals. But even at that remote time they were definitely and perfectly rodents, so that the fossils tell us nothing about the long series of intermediate forms that would be required to connect these highly specialized creatures with their earliest mammalian forbears. One of the most remarkable of the fossil rodents is the two-horned burrower shown in Plate 113. The skeleton of several kinds of these horned rodents, whose habits were probably like those of our pocket gophers, have been found in the western United States.

GANODONTA AND TILLODONTIA

Extinct mammals pertaining to the orders Ganodonta and Tillodontia bear a slight resemblance to the rodents in the chisel-like structure of their incisor teeth. Otherwise they are so different from them and from the members of all other orders that their exact relationships have never been satisfactorily explained. Both are apparently confined to rocks of Eocene age, the tillodonts in western North America, the ganodonts in western North America and in Switzerland.

HARES AND THEIR RELATIVES: LAGOMORPHA

Another order of mammals that resembles the rodents is the group made up of the hares, rabbits, and pikas. These animals have cutting teeth that work essentially on the rodent plan, consequently most writers have classed them among the rodents. But recent comparative studies have shown that the lagomorphs differ from the rodents in so many important details of structure as

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to give strength to the opinion that the two groups are not nearly related. The resemblances between them probably mean nothing more than that these different orders of mammals have independently developed similar cutting teeth.

Rabbits and hares (Plate 114, lower) are well known and of very wide distribution, their range extending from the Arctic regions south to southern Africa, southern Asia, including the islands of Sumatra and Java, and well down into South America. Several fossil species have been discovered, carrying the history of the order back to the Oligocene, but throwing no light on its origin.

The pikas, known also as little chief hares or conies, are common in the mountains of western North America and of Asia as far west as the Urals. During the Pleistocene epoch they inhabited most of North America and ranged, in the Old World, as far west as England. The pikas have short legs and short, round ears. (Plate 114, upper.) In general appearance they are thus more like guinea-pigs than rabbits. They especially delight in rocky places, and they are famous for the large stores of "hay" that they put away during the summer for winter use.

THE HOOFED ANIMALS AND THEIR RELATIVES: UNGULATES

Next to the rodents in success, as measured by the ability to produce great variety of form and structure and by the ability to make use of a multiplicity of conditions found on the surface of the earth, must be reckoned the great tribe of the hoofed mammals. As with the rodents, so with the ungulates, the controlling factor in their life economy is the eating of vegetable food. But while the rodents with their chisel-shaped front teeth are able to make use of every kind of vegetable substance, the ungulates—very few of which have cutting teeth at all resembling those of rodents—are as a group either grazers or browsers, that is to say, feeders on grass or feeders on the twigs and leaves of trees. To this rule,

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however, the omnivorous pigs form an exception. The hoof bearers have another peculiarity of habit as compared with the rodents: no member of the group is known to have learned to lay away supplies of food. Many of them therefore are compelled to make long seasonal migrations to escape starvation. These circumstances may well have placed a limit on the variety of forms that the hoof bearers have been able to produce, and they may also have had something to do with establishing the general tendency of these animals toward the building of large bodies. Whatever its origin, this tendency of the hoofed animals to become large of frame has had an important bearing on the study of extinct mammals: it has favored the preservation of ungulate fossil remains to such a degree that the ancient history of this group is better known than that of any other group of mammals. Therefore, the development of the ungulate group furnishes the most perfect guide that we possess to the understanding of the general process of mammalian evolution. Through the study of ungulate history we have been able to gain a clear idea of the steps by which such unlike creatures as the elephant, horse, cow, pig, deer, rhinoceros, and camel have evolved from ancestral types strikingly like each other in general appearance and utterly different in aspect from their descendants of today. And, perhaps more important still, we are enabled to infer, from our knowledge of the history of this group, what the probable course of events has been in other groups of mammals whose actual evolutionary history has not yet been worked out. Something of the general method by which paleontologists have deciphered the history of the hoof bearers was told in our account of the Badlands region of South Dakota. Now, as a specific example of one of the most complete mammalian fossil records yet known, we shall give an account of the development of the horse. But before doing this it will be best to survey the hoof bearers as a whole.

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Among the living hoof bearers and their allies there are several easily recognized kinds or types. First we have the even-toed group, so called because the third and fourth toes of each foot cooperate in doing most of the work of the foot. Sometimes, as in the cow, deer, and pig, these two toes alone support the weight of the body. In the hippopotamus they are assisted by the second and fifth toes. Next we find the odd-toed group. Here it is the third toe that is most important in function. The third toe may be assisted by the second, fourth and fifth, as in the tapir's fore foot, by the second and fourth, as in the rhinoceros, or may alone do all the work, as in the horse. Other mammals related to the true hoof bearers are the elephants and the less familiar African dassies or hyraxes. Elephants are too well known to require any description here. The dassies are small animals about the size of a marmot (Plate 115). Their toes are provided with pads that aid them in running over the surface of rocks and in climbing on rough tree bark. How these pads work is thus described by Mr. W. L. Sclater:

The soles, which are naked, are covered by a very thick epithelium which is kept constantly moist by the secretion of the sudorific glands there present in extraordinary abundance; furthermore, a special arrangement of muscles enables the sole to be contracted so as to form a hollow air-tight cup which, when in contact with the rock, gives the animal great clinging power, so much so that even when shot dead it remains attached to almost perpendicular surfaces as if fixed there.

Among the even-toed ungulates there are three sub-groups whose peculiarities call for a few words. First there are the pigs and their allies the hippopotamuses. They swallow and digest their food in the ordinary way, and their heads are never armed with true horns. Next come the innumerable cud chewers or ruminants, so named because they first swallow their food unchewed into one compartment of the stomach, then later force it

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back into the mouth for a thorough chewing, after which they reswallow it into a different compartment of the stomach where the regular process of digestion begins.

Practically all of the ruminants have horns, one on each side of the head, above the eyes, not on the middle line of the muzzle as in the rhinoceroses. These horns are of two kinds; namely, "solid" or "hollow." Hollow horns are found in cattle, antelopes, sheep, goats, and their allies. They consist of two parts—a bony core covered by a horny sheath, which, when removed, is hollow; whence the name "hollow horned." Hollow horns are rarely branched. Solid horns or, more properly, antlers, belong exclusively to the deer tribe. They consist of bone only, without a horny sheath. Every year they are shed and renewed. The growing horn is covered by a delicate skin, rich in blood vessels, and known as the velvet. This skin dries and peels off when growth is complete. Antlers, as may be seen from Plates 119 and 120, are usually branched. In some deer as, for instance, our moose and the extinct giant deer, or Irish elk, of the European Pleistocene, they appear to have developed beyond the offensive and defensive needs of their bearers. This is especially true of the giant deer, a skeleton of which, together with a skeleton of the mule deer, is shown in Plate 120. The strain on the vitality of the animals imposed by their great size and by the necessity of a yearly making and throwing away of a quantity of bone almost half as great as that of the skeleton proper may well have been a factor in the extermination of the race.

In addition to these groups of living hoof bearers there are several groups that are now extinct. Among these are the protungulates, of the oldest Eocene formations, animals in which peculiarities indefinitely ungulate are combined with others that suggest the carnivores. With one exception protungulate remains have been found only in western North America; the exception comes from Europe.

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NOTUNGULATA

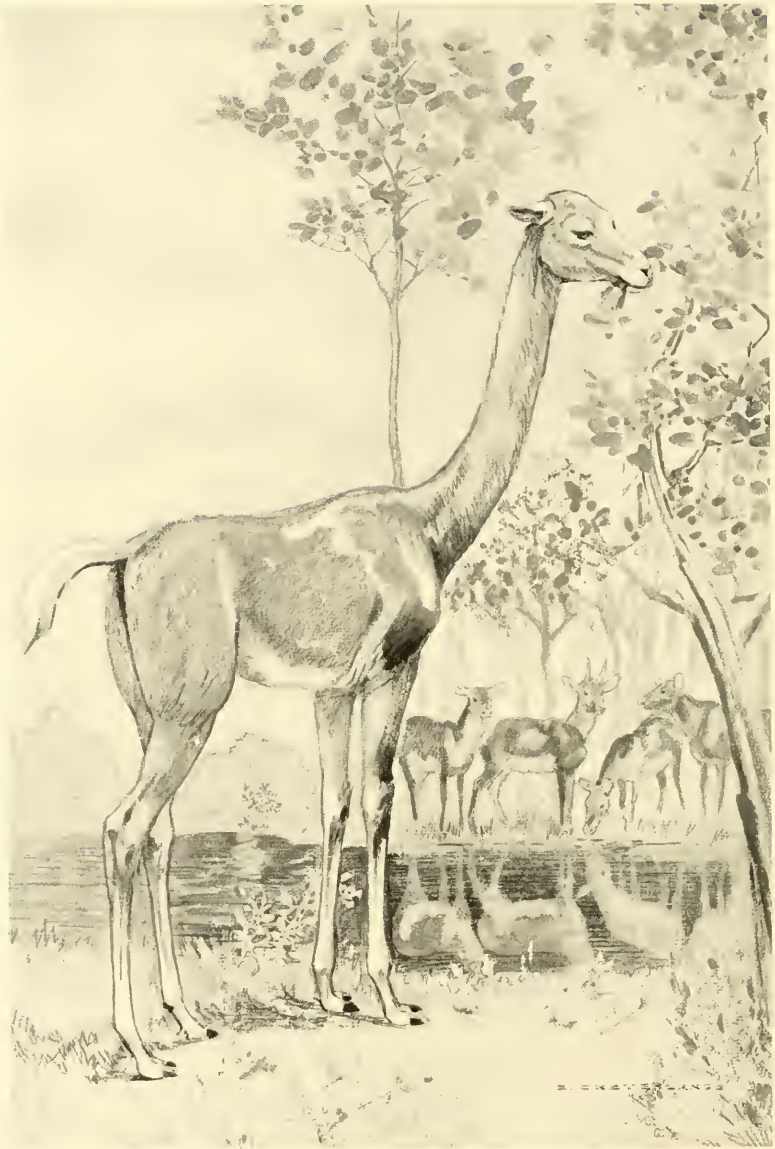
During the millions of years of the Tertiary period there lived and developed in South America a great group of mammals, very diversified in kind and mostly large in size, which, though related to the hoofed animals in general, formed a distinct order of their own. Almost nothing is known of their ancestry and they have left no descendants. This great group has been given the name Notungulata, which means literally "south hoofed animals," in reference to their geographic range. For a long time the Notungulata were supposed to have been confined to South America, but in recent years fragmentary remains of an animal related to these strange South American hoof bearers have been found in the early Tertiary rocks of western North America.

These ancient South American hoofed animals, like the Australian marsupials, present many striking instances of developmental lines running parallel to those that are found elsewhere among unrelated animals. Thus one group of them, known as the Toxodontia, so named because of the peculiar bowed form of the cheek teeth, were remarkably like the rhinoceroses in tooth and foot structure as well as in general bodily build. Another group, the Litopterna, or "smooth-heel bone," in allusion to a peculiarity of the hind foot, was very horselike both in general appearance and in the specialization of the teeth and feet. The later members of this group were more completely single-toed than the modern horse. A third group, the Pyrotheria, curiously paralleled some members of the elephant family.

The best known and most characteristic member of the Toxodontia is the animal to which the name *Toxodon*, or "bow-tooth," was given. In life this beast was a massive creature that would have rivaled the largest of the rhinoceroses in bulk, though not in height. The teeth of *Toxodon* are peculiar in that the incisors are developed



Rocky Mountain goats, found only in the mountains of western North America. This goat has no near relatives in the Old World. Group in the National Museum



Restoration of a New World camel, *Alticamelus giraffinus*, which lived during the Miocene epoch. It was about equal in size to a modern camel, but had excessively long legs and neck. In the background are several animals of the species *Dromomeryx borealis*, closely related to the true antelopes of today

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in tusklike form. Both the incisors and the cheek teeth are of the highly efficient kind that continue to grow from the base as the crown wears away, a type of tooth still found in some of the rodents and in the rodentlike marsupial wombat.

A closely related and somewhat smaller member of the toxodont tribe is *Nesodon*, a name meaning "island tooth," in reference to an isolated lobe on the inner side of each of the upper cheek teeth. It shows little resemblance to any animal living today.

Another group of these South American hoofed animals was represented by several kinds, some of which more or less resembled the present-day llamas of the Andes; others were quite horselike in appearance. The camel-like animals were best represented by the genus *Theosodon*, literally "fortune-tooth." For what reason this name was chosen for the genus is not apparent, unless the author considered them fortunate in having teeth of such form as to make them formidable in repelling foes.

The extinct animal that most closely resembled the horses is represented by *Diadiaphorus*. This animal paralleled especially the three-toed horses of the late Tertiary period both in tooth structure and modification of the feet. The latter were so much simplified that they had a single functional toe, though they retained the small disappearing lateral pair, as did *Pliohippus* among the extinct North American horses. A nearly related animal, *Thoatherium*, the name meaning "active-swift-beast," while smaller and in many respects more nearly like the horses of the middle Tertiary (*Mesohippus*), had gone much farther than even the living horses in the reduction of lateral toes. In fact, this animal was more strictly one-toed than any other known mammal. It must have been a graceful and swift runner, though its rather short legs would have made it less swift than a modern horse.

One of the strangest of these unusual early South

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American beasts was the *Astrapotherium*, literally "lightning-wild-beast," a name given it by Burmeister on account of its supposed analogy to the great rhinoceroslike *Brontotherium* ("thunder-wild-beast") of the North American Oligocene. This animal had also some resemblance to the mastodons, the most striking difference being the more normal position of the tusks and the less modified development of the proboscis.

AMBLYPODA

But North America also, in former geologic epochs, had its own peculiar groups of hoofed mammals, all the genera of which are now extinct, as are all the genera of the South American Notungulata. These extinct North American groups of ungulates are known as the Amblypoda and the Condylarthra. In that long-ago time when the Rocky Mountains were in their infancy, there might have been seen in certain regions of the western United States herds of hoofed mammals known as Amblypoda, so unlike any creature living today that it is difficult to find a familiar creature with which to compare them. Though related in a general way to the living ungulates, the amblypods formed a distinct group, which ran its course of evolution to the end and then perished, leaving no descendants.

Largest among the amblypods were the uintatheres, or "Uinta-beasts." These ungulates were almost elephantine in size, and were built somewhat according to the proportions of the elephant, except that their legs were shorter and their necks were relatively much longer, so that the uintatheres could graze after the manner of rhinoceroses or cattle, that is to say, by bringing the mouth to the ground, something that an elephant can not do. But the feature that especially distinguished them was the very peculiar development of the head, which was furnished with three conspicuous transverse pairs of smooth bony prominences resembling horn cores. The

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largest pair was situated near the hinder portion of the long, slender skull; the pair next in size was placed about the middle of the skull and directly over the eyes; and the third and smallest pair occupied a position near the extreme end of the nose. The uintatheres also bore a very formidable pair of tusks, or enlarged upper canine teeth. These were flattened and curved like saber blades, and their tips extended downward toward the lower border of the lower jaw, which was provided with a bony flange apparently used to protect the long canines if subjected to a lateral blow. This unusual development of tusks and jaw flanges was closely paralleled in the quite unrelated great saber-toothed tigers of a much later age. Considered alone, the presence of carnivore-like cutting tusks might suggest ferocious animals of flesh-eating habits. But the cheek teeth and whole anatomical structure show that the uintatheres were plant eaters and probably no more bloodthirsty than the herbivorous musk deer and water deer of today, both of which differ from their living relatives in the possession of enlarged canines. It is conceivable that the great tusks were used to pull down branches of shrubs or vines, on the leaves or fruit of which the animals fed; in fact there is even some reason to suppose that these canines were developed in response to the needs of peculiar feeding habits, as those of old individuals are always much worn. But the tusks of the uintatheres can not be certainly accounted for any more than can those of the living musk deer and water deer. Both males and females possessed them; hence this specialization can not be attributed to sex.

Still another conspicuous family included among the amblypods is the Coryphodontidae. These ungulates, about the size of a Jersey cow, belonged to an earlier part of the Eocene epoch than did the uintatheres, and some member of the group may have been the forerunner of the "Uinta-beasts."

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CONDYLARTHRA

The other North American group of extinct ungulates is known as the Condylarthra, a name proposed to designate several families of extinct mammals, all of primitive or generalized type but resembling in a general way the living hoof bearers. Their remains have been found for the most part in the western United States. They form a natural assemblage whose members had many characteristics found in the two major divisions of living ungulates, or hoofed animals—Perissodactyla and Artiodactyla—but they were probably not ancestral to either of these. They were contemporaries of the Amblypoda, flourishing during the early part of the Age of Mammals, and thus confined to the Paleocene and Eocene epochs.

The known members of the Condylarthra were all small, the largest not exceeding a big wolf or dog in size. The best known, and perhaps the most discussed, has been given the name *Phenacodus* in reference to the puzzling character of its teeth. It was an animal about the size of a leopard or a Newfoundland dog, but with relatively larger feet, shorter limbs, shorter neck, and longer tail. Each foot had five well-developed toes, which, however, bore small, flattened nails, or hoofs, instead of claws. The feet were nearly plantigrade, much as in bears and men, and the structure of the whole animal was primitive. But many features marked them as being closely related to the ungulates, or hoofed animals. In fact they were long regarded as ancestral to most of the later extinct and present-day orders of this great group of mammals, and at one time they were even considered as the direct forerunners of the horse family. But our increased knowledge of ancient mammals has proved that this belief has no real foundation, and *Phenacodus* and the entire group to which it belongs are now regarded as primitive creatures closely related to all of the later hoofed animals but not directly connected with any of them.

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BARYPODA

Standing somewhat between the amblypods and the elephants is an extinct group known as the barypods, discovered in Oligocene beds in Egypt. They had teeth of nearly uniform character arranged in a continuous row not broken by spaces. Over each nostril rose an enormous horn directed slightly forward, while behind each eye a small horn projected backward.

MORE FAMILIAR TYPES

When we look at the extinct members of those groups that are still represented by living kinds we find a bewildering array of creatures strange to us but in their day only the ordinary beasts of forest and field.

America during the Pleistocene, the epoch just preceding our own time, was the home of animals that today exist only in Africa and Asia. Elephants roamed in great herds over wide expanses of Central and North America, extending their range during the warm interglacial epochs over the northern United States and as far north as the Arctic Circle in Alaska. There were several kinds of American elephants, some of them even exceeding in size the largest elephants of the African and Indian jungles today. Four of these were closely related to each other and to the present-day Indian elephants. These are generally classed in the group known as the mammoths, though this name was originally applied only to the far northern animal, whole carcasses of which have been found in the frozen soil of Siberia. Common American and Old World animals, related to the elephants, were the mastodons. These are distinguished from the elephants by the form of the teeth. In the mastodons the teeth were low-crowned, much like those of a pig, while in the elephants they are very high-crowned, with the enamel arranged in vertical plates set transversely and pressed together like the leaves of a book. Rather curi-

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ously, the name mastodon has been transferred to the elephants in Alaska, where elephant remains are abundant but mastodon remains are excessively rare.

These great creatures of the elephant family, all of which are now totally extinct, must have continued to exist almost to the dawn of historic time. In Europe accurate representations of the mammoth carved in ivory and painted on the walls of caves show that the animal was well known to the human inhabitants of the country. Furthermore the excellence of these pictures leaves little room for doubt that the men who made them possessed a mental equipment scarcely if at all inferior to that of the European of today, however primitive they may have been in their mode of life. In Siberia the frozen mammoths are so perfectly preserved that their stomach contents have been examined and found to consist of the same plants that are growing on the spot today. In North America we have found much evidence to lead to the belief that elephants and mastodons were contemporary with man. Bones and teeth of both of them as well as remains of other extinct animals have been found associated with human remains in a manner to convince paleontologists that they were deposited contemporaneously. It is beyond question that elephants and mastodons became mired in swamps formed on the surface of deposits left by the last great ice sheet during its northward retreat. These creatures must therefore have survived the rigors of the Glacial period. In South America a mastodon skeleton has recently been found under circumstances that led its discoverer to believe that the animal was killed by the Indians with spears; while as long ago as 1839, one was found in Missouri associated with Indian artifacts and with stones evidently brought from some distance. Both of these skeletons had been partly burned.

Why the elephants and mastodons, after living through the Ice Age, should have then completely died out in

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America and in the northern part of the Old World is one of those mysteries that we everywhere find in the story of mammals. Their extinction certainly can not be explained as the result of some great disaster that swept from Argentina to Alaska, and from Siberia to Spain. It rather gives support to the idea that groups of animals, like individual animals, have a natural life course leading to natural death, and that the great size and very peculiar structure of the elephants and their allies are not so much the marks of racial vigor as the signs of approaching racial end.

The camels also are animals that have had a wide range of development. As with the horses and rhinoceroses their life history is most closely connected with America. Little animals no bigger than rabbits that lived near the beginning of the Tertiary are the earliest known representatives. In the time of the pre-Badlands plain building, they were beginning to assume camel-like proportions, although still of no great size. But their chief development occurred during the ages following the pre-Badlands time. During this later period a great variety of camels existed. Some of these animals may have given rise to the camels of the Old World, others were probably forerunners of the South American llamas, while still others left no descendants. Among the latter were several of large size that developed a long neck and very long legs like those of the present-day giraffe, except that the fore and hind legs were of nearly equal length, whereas in the giraffe the fore legs are longest. One of these long-legged kinds of camels is shown in Plate 118.

It will immediately be seen that this animal, while agreeing with the present-day Old World camels in general characteristics, is curiously different from all of its living relatives. Not even the slender llamas of South America have such a form.

When we look at other extinct members of this group

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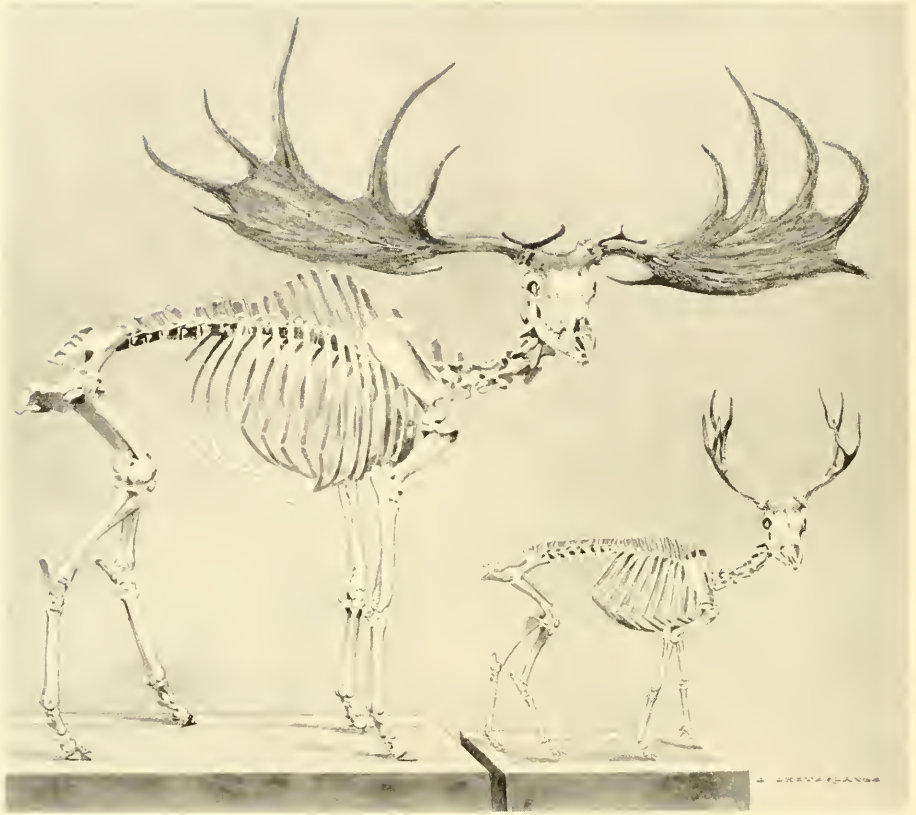
we find three conspicuous even-toed hoofed mammals living in the United States during the Pleistocene age: Great bisons with horns spreading seven or eight feet from tip to tip; muskoxlike animals double the size of their living relatives of the north country; and very large piglike animals, members of the peccary family but exceeding in size their relatives now living in Mexico and in Central and South America.

Even more remarkable, perhaps, are some of the creatures among the odd-toed ungulates that have run their course to perfection and death. In our account of the Badlands we have described some of the relatives of the rhinoceros that once inhabited the United States in unnumbered multitudes. A member of the same general group is the *Baluchitherium*, of the Mongolian Miocene, the largest land mammal that has yet been discovered. Exceeding the heaviest elephant in bulk, the baluchithere had the general form of the living rhinoceros, although with a very unusual development of neck; but the baluchithere was not so robust as the rhinoceros and not so long-legged and long-necked as the giraffe. Its length, not including neck, was about fifteen feet; its height at shoulder was about thirteen feet, and to the top of the head in normal pose about twenty feet. The skull and teeth were not very different, except in size, from those of living rhinoceroses; but the snout did not bear a horn.

Best known and perhaps most interesting of the extinct odd-toed hoof bearers are the many creatures that have their place in and near the ancestral line of our familiar domestic horse. The story that they tell is vivid and well known in all its most important episodes. It is also one of the most complete and most easily understood illustrations of the gradual evolutionary change from ancestors of one kind to descendants of another kind so different that without knowledge of the intermediate stages no relationship could be imagined to exist. For



Alaskan caribou. This animal is the wild North American representative of the Old World domesticated reindeer. Group in the National Museum



Skeletons of the extinct giant deer of the European Pleistocene and the living American mule deer drawn to the same scale to show difference in size. The giant deer stood nearly six feet high at the shoulders. It grew and shed a new pair of enormous antlers each year. Specimens in the National Museum

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these reasons we shall now relate the story of the horse in some detail.

EVOLUTION OF THE HORSE

To most of us the name *horse* signifies the domestic animal only. The naturalist gives a wider meaning to the word, however, for he applies it not only to the domestic species of horse, but also to its living relatives—the asses and zebras native to the Old World—and to a very large number of nearly related extinct animals that inhabited the earth long ages before human records began.

Those earlier horses were far more numerous and diversified in kind than the horses existing today; and, as we read their record backward, we find them less and less like their living successors. Thus, penetrating the past, we find, at the beginning of the Pleistocene epoch, or Ice Age, horses closely similar to, yet differing from the modern horse, which had not yet appeared. Going farther back, we find horses that were smaller on the average and a little less perfected in the structure of their feet and teeth. Still farther back they were even less specialized, and so on to the earliest time in which they have left a record. Here we find that they were all very small in size and primitive in type. But however different from each other and from existing kinds they may seem to have been, these extinct creatures had a structure which conclusively proves that they belonged to the same natural group of animals as does our familiar domestic horse.

As these ancestral horses have left a great abundance of wonderfully preserved fossils in the sedimentary rocks and softer formations that were slowly built up through the long ages of the past, their story can be read with an unusual degree of detail. In these formations have been found the fossil remains of a progressive series of forms. These fossils reveal a line of development, with few serious breaks in it, from the earliest and most primitive little

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horses to the most recent and most wonderfully perfected equine creatures that live today. Many well-preserved skulls and some more or less complete skeletons of the horses belonging to each geologic age have been collected and studied. Our knowledge of the relationships of the extinct horses and our attempts at the reconstruction of their complete bodily forms are therefore based on sufficiently adequate and abundantly observed facts to make them reliable and reasonably accurate. In no sense, then, can our conclusions be justly called mere guesses and baseless conjectures, as some uninformed persons have assumed them to be. From the fossil records, indeed, we know the history of the ancient horses more surely than we know the history of some ancient civilizations from human records.

The history of the camels, llamas, rhinoceroses, and some other mammals have also been rather fully recorded in the rocks; but since these life stories are so similar to each other in general features, that of the horse may be taken as typical of what has happened in all lines of mammalian life during the course of their progress up out of the past and onward to the present, or to extinction.

From the rock records we find that the first known ancestors of the horse lived in the early Eocene, near the beginning of the Tertiary period or Age of Mammals, a time separated from the present by perhaps forty million years or more. The horse ancestors of that age were diminutive creatures, none of them larger than a fox, and of several closely related kinds. They had a wide geographic range, their remains having been found in the Eocene rocks of both Europe and North America.

The North American member of this early group has been given the very appropriate name *Eohippus*, or "dawn-horse" (Fig. 25). *Eohippus* was a graceful little animal, perhaps the most agile runner of his time; for even at that early period he had begun to develop the

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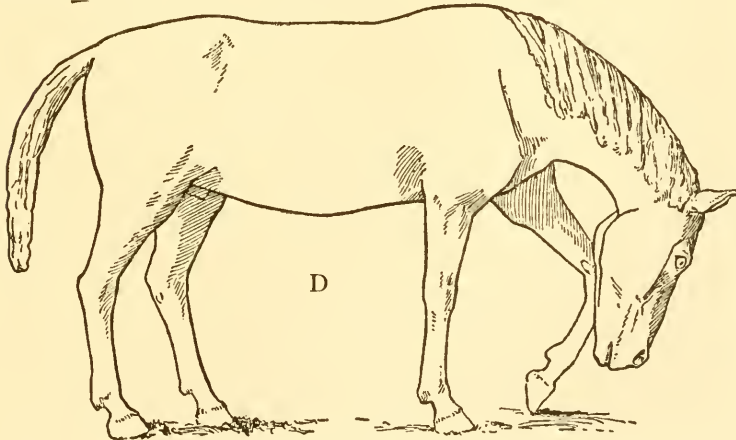
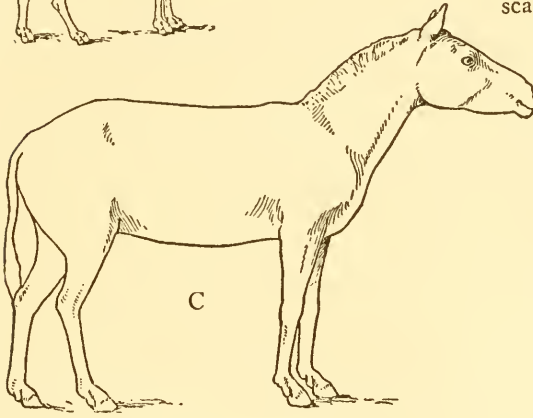
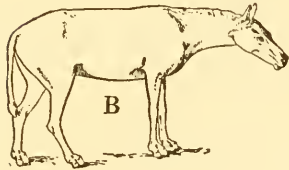
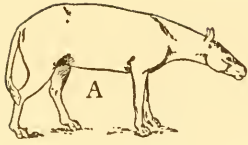


FIG. 25. Four of the principal stages in the evolution of the horse: A, *Eohippus index*, or "dawn-horse," the earliest known, representing the early Eocene stage; B, *Mesohippus bairdi*, or "middle-horse," representing the Oligocene stage; C, *Neohipparion*, or "new-pony," representing the late Miocene and early Pliocene stage; D, *Equus scotti*, representing the Pleistocene and Recent stage. Models based on actual skeletons and all made to the same scale

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type of leg and foot that now, millions of years later, makes our highly bred race horses such marvels of speed.

The primitive or foundation type of foot, out of which, as we pass forward in time, we find that the foot structure of all mammals has developed, is a bearlike, flat foot, such as we ourselves have, with five toes and a heel that rests on the ground. From this type all sorts of feet have evolved: some for swimming, as in the seals; some for climbing, as in the apes, monkeys, and squirrels; and a great variety of others adapted to different ways of moving and living on the ground. Among these last the foot of the horse, built for running, is in many respects the most highly specialized, or farthest removed from the primordial type. In the modern horse the five toes are reduced in number to a single one on each foot; the heel ("hock joint") of the hind foot and wrist ("knee") of the fore foot are raised high off the ground; the single toe is greatly lengthened; and the animal walks on the tip of his middle-finger nail. This foot structure, together with the shortened upper-leg bones around which the powerful muscles of the thighs and shoulders are massed, makes a machine peculiarly adapted to long strides and great speed. On examining the foot of our little dawn-horse, we find that it had already reached a stage in development well in advance of the primitive bearlike or manlike type, though still far away from that of the present-day horse. The feet of *Eohippus* had the ankle and wrist joints raised high off the ground, but the fore foot had four toes of nearly equal size and a remnant of a disappearing great toe (technically styled Digit I), whereas the hind foot had three toes, the middle one of which was largest. This little horse had, therefore, not yet arrived at that stage of evolution where the entire body weight is borne on the tips of the toes. He still carried part of his weight on small pads like those now found on the feet of a dog, a disappearing remnant of the broad primitive sole that has persisted in man and bear.

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The head, teeth, and other parts of this early horse, too, are quite different from the corresponding parts of its present-day descendants. For example, the muzzle of the domestic horse is very long, and the lower jaws are very deep to accommodate the high-crowned cheek teeth that are set in them. The muzzle of little *Eohippus*, on the contrary, is relatively short, so that the eyes are situated about midway between the tip of the nose and the ears; the teeth are low-crowned, and the jaws are slender and shallow.

And so on throughout the other parts of the skeleton of *Eohippus*, we find marks of primitive structure. When we compare the dawn-horse with the living horse we find many differences, so many indeed, that if intermediate forms had not been discovered, the differences would entirely obscure the relationships that really exist. So true is this that when a crushed skull of one of these little creatures was found in the ancient "London clays" of England at a time when none of the later, or intermediate, horse forms had been discovered, even an anatomist so experienced as Owen was unable to recognize the true relationships of the fossil. Because of a superficial resemblance in the teeth to those of the African hyrax, or dassie, he quite naturally gave his specimen the name *Hyracotherium*, or "hyrax-beast," signifying its supposed affinity to the living African dassies, a group of mammals with which it was afterward learned to have only the remotest kinship. But soon after this skull was found, there began the series of discoveries in North America that brought to light one after another the intermediate series of animals, thus revealing the true relationships of the English hyracothere and our own little dawn-horse, and gradually supplying the links of the ancestral chains that connect both of them with the horses of today.

The reader has already been made acquainted in Chapter II with one link of this chain, namely the *Meso-*

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hippus, or "middle-horse," which, as we have already seen, was so abundantly represented in South Dakota during the upbuilding period of the pre-Badlands plain (see Plate 77, page 196). These horses, it will be remembered, were quite small, yet they were notably less diminutive than the dawn-horses, and they showed other marks of progress in development toward the present-day form. Not only were the toes of their fore feet reduced to three, but the central toe was much enlarged, while the two remaining lateral ones had become very slender (Fig. 25). Thus these animals had reached the stage at which, in walking, they bore the greater part of their weight on the end of the middle toe. Also their muzzles had become longer than those of the little dawn-horses. This modification of the skull was required to permit the lengthening of the cheek-tooth rows and to insure a better development of the nipping or grazing teeth. These and other characteristics of the middle-horses marked a long step in advance of the dawn-horses; but the gap between the two kinds is almost, though not completely, bridged by the structure of several animals whose remains have been found in rocks laid down during the long interval that intervened between the days of the dawn-horse and the middle-horse.

At the time when *Mesohippus* inhabited the Dakota Badlands, all the horses in the world, and there were many of them, were three-toed, with the upper sections of all the digits considerably lengthened and the middle toes much enlarged. But the lateral toes in all of them still reached the ground and bore some small part of the body weight when the animals stood at rest. By this time, however, most of the weight had been shifted to the middle toe, so that it was supported partly on the tip of this toe and the thickened, modified toenail, or hoof, and partly on the doglike pad of the foot.

The middle-horses retained the short-crowned type of tooth that they had inherited from their ancestors, the

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dawn-horses; but the three anterior cheek teeth in each jaw, which were small, simple-cusped, and triangular in form in the dawn-horses, had now become enlarged and altered to resemble the quadrate true molars, or hinder grinding teeth. In fact, the cheek teeth of these "intermediate" horses had reached the stage in development that forms the basic pattern on which the teeth of all later horses were to be built. The transition is beautifully shown in *Orohippus* and *Epihippus*, two intermediate forms of the upper Eocene. *Orohippus* had one molariform premolar, *Epihippus* two, and our intermediate horse, three.

From this intermediate stage on to that of the present day, the advance in cheek-tooth development had to do principally with the heightening of the crowns and the adding of a new, bony, tooth substance known as cement. This new material became, as the crown heightened, more and more an essential part of the tooth. In the very high-crowned type of tooth found in the modern horses, for example, this hard cement deposit has filled all the interspaces between the greatly heightened, enamel-covered cusps and has surrounded the entire crown, giving the teeth great strength and solidity.

The steps by which this process of tooth development was accomplished, as well as the continued gradual diminishing and final disappearance of the lateral pairs of toes, may be followed in minute detail through the various kinds of horses whose remains have been discovered in successive levels of the two thousand feet or more of sedimentary deposits which, in their aggregate, entirely fill in the time gap between the days of the middle-horses and the present. Thus at the beginning of the Miocene, the geologic epoch that immediately succeeded the time of the middle-horse, we find a group of horses with cheek teeth slightly higher than those of *Mesohippus* and showing the first traces of cement, and with feet whose toes have made a slight but definite advance toward the

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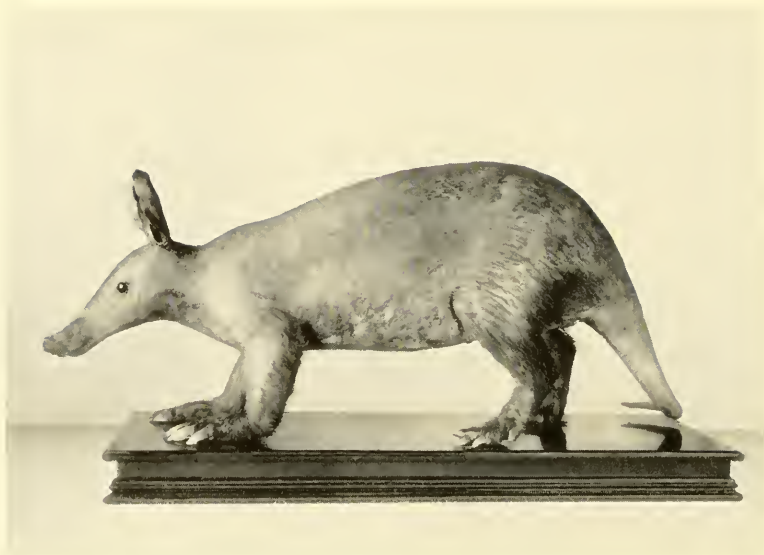
modern type. This genus has been given the name *Parahippus*, which signifies "near-horse." The next step may be seen in the horses of a little later time, known as *Merychippus*, or "ruminant-horse." In this genus the milk or colt teeth are similar to the adult cheek teeth of their predecessor *Parahippus*. The adult cheek teeth of *Merychippus*, however, are noticeably more advanced in type than those of *Parahippus*. They have become higher-crowned and fully cemented; but their height, which still only about equals the width of the crown, is very moderate as compared with that which has finally been attained in the modern horses, where the height of the crown is three times the width.

After the *Merychippus*, still larger and otherwise more advanced horses were developed. They filled in the interval between the older types and the strictly modern animals that began to appear rather abundantly in North America early in the Pleistocene or "Glacial" period.

The first of these latest preliminary evolutionary stages of the modern horse is the *Protohippus*. It lived in the later part of the Miocene. The name means, literally, "before-the-horse." Its tooth crowns were moderately heightened in both young and old and its side toes were greatly reduced, though still large enough to be of some use. The small, doglike pads mentioned as present in the feet of the earlier horses, probably disappeared at this stage. *Hipparion*, the Greek name for "small-horse" or "pony," and *Pliohippus*, a name signifying "Pliocene-horse," genera of the early Pliocene age, had reached a stage where the lateral toes were no longer useful. Though still present these toes were on the point of disappearing. In the horses of the later part of this epoch, the lateral toes had entirely disappeared and the stage of single-toedness that we find in the foot of the modern horse had at last been reached. But as in *Plesippus*, a name signifying "near-horse" given to a genus that flourished at this time, certain intermediate characteristics still



Three-toed sloth, a mammal that lives in tropical America. It has become so highly modified for tree life that it has great difficulty in walking on the ground. Specimen in the National Museum



Two ant-eating mammals

Upper: Aard-vark, an African mammal distinguished by its long head, long ears, muscular tail, and powerful claws. It feeds chiefly on white ants. Lower: Great anteater of South America, with powerful claws to break open the nests of white ants and a long, sticky tongue to lick up the insects. Specimens in the National Museum

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persisted. For example the first, or anterior, tooth of the upper cheek-tooth series on both sides, present in all earlier horses and usually absent in modern horses, is still present and functional in *Plesippus*, and there are remnants of two bones in the fore foot likewise absent in the modern horse and normally present in earlier forms.

Thus the last gap between the three-toed and single-toed kinds of horses has been bridged, and we come to the final geologic epoch preceding the present, known as the Pleistocene. In it we find that all the horses throughout the world were single-toed, long-muzzled, deep-jawed, and in every respect quite modern in type.

At this time horses were very numerous in kinds, and although most of their evolution seems to have taken place in North America, they had found their way into Central and South America, Asia, Europe, and Africa. Strangely enough, they became extinct in the Western Hemisphere long before the coming of the white man. Today they survive in the natural state only in parts of Africa, where they are represented by the common wild ass and three kinds of zebras, and in Asia, where they are represented by one true wild horse and two peculiar kinds of wild asses.

In this brief outline of the development of the horses, only the principal forms have been included in our descriptions; and no mention has been made of the many aberrant or divergent kinds whose lines branched off at various places along the road extending from the early Eocene, or "dawn time," up to the present. There were many such lines and their history gives abundant evidence that there was always present among the members of the horse tribe a tendency for some to develop in directions away from the main course and soon to become extinct.

SLOTHS, ARMADILLOS, AND THEIR ALLIES: XENARTHRA

The order that includes the living armadillos, anteaters, and tree sloths, together with their extinct allies,

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the ground sloths (see Plate 90, page 240) and glyptodonts, is, and so far as the fossil record shows, always has been exclusively American. It is one of the groups of mammals that developed in South America during the long period of isolation to which we have already several times alluded. When land connection between the two continents of the Western Hemisphere was again established, ground sloths and glyptodonts invaded North America. The living members of the order are only a small fraction of the great sloth population that once existed.

Our present-day sloths, of which there are three genera, one of which is shown in Plate 121, are small animals, not much larger than the domestic cat, with round heads, flat-topped teeth, shaggy, coarse fur, slender legs, and long, curved claws. Spending all of their lives in the trees of the tropical forests, they have great difficulty in moving about on the ground; and their favorite mode of progression is to swing slowly along, back down, beneath the branches, to which they suspend themselves by their claws. Their relatives the ground sloths, once very numerous, are now extinct, though the last of them continued to exist until not long ago, geologically speaking. Remains of one kind have been found in Patagonia under circumstances appearing to show that the animal had been walled into a cave by early Indians. In Texas the bones of another kind have been found in two different caves; in one cave they were associated with human bones, and in the other they were so fresh that the entire skeleton was still bound together by its ligaments. A foot bone of a third kind has been dug from a heap of Indian food refuse in the Dominican Republic. The smallest ground sloths were about the size of small pigs. The largest were enormous creatures whose bulk must have been almost that of an Indian elephant, but whose general aspect (see Plate 90) was strikingly different from that of any creature now living.

The anteaters (Plate 122) are related to the sloths, but

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are easily distinguished from them by their elongated heads, tubular muzzles, and toothless mouths. As their name implies these animals feed on ants and termites, which they lick up with their long, extensible, wormlike tongues covered with sticky saliva. There are three genera, all confined to the forests of tropical America.

The armadillos (see Plate 92, page 244) are distinguished from the sloths and anteaters, as well as from all other living mammals, by the circumstance that their backs and sides are covered with an armor of bony plates closely fitted against each other and so arranged that in the middle of the body they form movable cross bands. These bands permit the animals to roll themselves into hard-shelled balls impervious to the attacks of ordinary carnivorous enemies. There are about a dozen principal kinds of living armadillos, one of which, the nine-banded, now ranges northeastward across Texas into Louisiana and is every year extending its area of dispersal.

Many fossil armadillos have been discovered, chiefly in South America. They show that the group has been well represented since the Oligocene and perhaps since earlier times.

Superficially resembling the armadillos, but not very nearly related to them, were the glyptodonts (Plate 123), which flourished in South America from Miocene to Pleistocene days and penetrated far into North America during the Pliocene. Like the armadillos the glyptodonts were covered with bony plates; but, unlike them, these plates were closely and uniformly fitted against each other to form a shell as solid and immovable as that of a turtle. In a majority of genera the plates were thus closely fitted together over most of the body, and in some genera over the whole body. In the largest kinds the solid shell thus formed was as much as seven or eight feet long and five to six feet wide. The long, heavy tail, was variously incased in bony rings and sheaths.

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PANGOLINS: NOMARTHRA

A body covering of horny plates, not fitted together like the bony plates of armadillos and glyptodonts but overlapping each other like shingles or roof tiles, is the most obvious characteristic of the pangolins (see Plate 92, page 244). These animals are toothless eaters of ants and are found in the Malay region and in Africa. With their short legs and long scaly tails tapering gradually away from their slender bodies their general aspect suggests a reptile rather than a mammal. Six principal living kinds are known, all but one of them African. The pangolin group is an ancient one, as two fossil members of it have been found in the Eocene deposits of western Europe.

Though the pangolins are all toothless and apparently incapable of offensive action, at least one of them has an unexpected method of injuring its enemies. Mr. Austin Roberts tells us of a certain African species: "After rolling up when handled it opens and closes with a quick jerk, each scale closing on the next with great force, and its sharp edges closing on the fingers of a man or paws of an animal would probably cut them off."

AARD-VARKS: TUBULIDENTATA

Aard-varks are now confined to Africa, though the remains of related animals have been found in Oligocene and Miocene rocks of Europe and in the Pleistocene deposits of Madagascar. The living species are about the size of ordinary pigs and are somewhat piglike in general build except for their long, muscular tails (Plate 122). Living in burrows by day they naturally acquired the name "aard-vark," the Dutch equivalent of our word "ground-hog." At night they roam about in search of the nests of white ants, or termites. Easily breaking through the sun-baked walls of these nests with their heavy claws they leisurely feast on the teeming inhabitants. Unlike the ant-eating pangolins and the true ant-

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eaters of South America the aard varks have teeth. These are flat-topped and of a very peculiar microscopic structure that has suggested the technical name of the group—Tubulidentata. All the living aard-varks belong to essentially one species.

SEACOWS: SIRENIA

So highly modified for aquatic life that their hind limbs have been reduced to mere rudiments lying entirely inside the body and their fore limbs changed into paddles or flippers, the seacows appear at first sight to be quite unlike any other mammals (Plate 124, upper). Though they pass their entire lives in the water, they are heavy-bodied, slow-moving plant eaters with little of the fishlike appearance of whales and porpoises. Seacows, indeed, are so heavily built that they seldom venture far from land. They seek the protection offered by coasts, estuaries and wide, placid rivers. Here they can find shelter from storms and can procure an abundance of vegetable food. Though so peculiar in general appearance the seacows are shown by their anatomy and by the structure of their extinct relatives to be somewhat allied to the elephants; and it is not improbable that the ancestry of these two seemingly unlike tribes of creatures may eventually be traced back to a common stock.

At present there are living seacows of two genera: The dugong, which is provided with tusks in the upper jaw, and the manatee, which is tuskless. Both genera are tropical in habitat. The manatee, of which there are several species, is found in the Atlantic region, either along the coasts of that ocean or in its fresh-water tributaries. One species is native to African waters, the other two or three inhabit American waters as far north as Florida. The one species of dugong is distributed along the coasts of the Indian Ocean from Australia to the Red Sea and Africa. Thus it will be seen that the sirenians are now confined to warm regions; and the individuals of

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one species at least, the Florida manatee, are so sensitive to cold that they have been occasionally killed in considerable numbers by the fruit-destroying frosts that periodically visit the State. But strangely enough, as recently as two hundred years ago, there existed a northern species of sirenian. When Bering's last, ill-fated voyage of discovery ended in shipwreck, November 5, 1741, on the northern island that now bears the commander's name, the survivors found there not only an abundance of priceless sea otters and scarcely less valuable Arctic foxes, but also huge seacows of a totally unknown sort. These animals, unlike all other sirenians, successfully braved the rigors of a northern climate. They were toothless, and their food consisted of seaweeds, particularly the laminaria, or kelp. Perfectly defenseless as they were, the wreck of Bering's ship was more of a disaster to them than it was to the explorers on board the vessel. Some of the men were able to survive and return to their homes; but the unfortunate sirenians, once discovered, were completely exterminated by Russian sailors within the next twenty-seven years.

Fossil seacows of many kinds have been found in deposits ranging in age from Eocene to Pleistocene. Some of the earlier sorts had not yet entirely lost the hind legs of the typical mammalian structure.

WHALES AND PORPOISES: CETACEA

Of all mammals the whales and porpoises are the ones that have undergone the greatest and most surprising changes of bodily structure. For we have good reason to believe that they have been gradually transformed, in the course of countless ages, from land-inhabiting creatures with four legs and a somewhat doglike appearance into warm-blooded images of fishes, perfectly fishlike in mode of life except that, unlike fishes, they must rise to the surface of the water at frequent intervals to breathe atmospheric air.

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About cetaceans there are many popular misconceptions. For instance, it is not by any means generally understood that these fishlike marine creatures are not fish but mammals. All whales and porpoises are warm-blooded air breathers that bring forth perfectly formed living young and nourish them with milk. We have been unable to find any clear account of the exact way in which a young whale or porpoise obtains its milk without getting it too much diluted with sea water. But the milk glands of the mother are large, and milk has been found in the stomach of the young; so there is no doubt that suckling actually does take place.

A curious idea quite generally entertained, even by men who have actually cut up many whales, and who might therefore be expected to know better, is that the shoulder blade of this cetacean belongs in the finlike end of the tail.

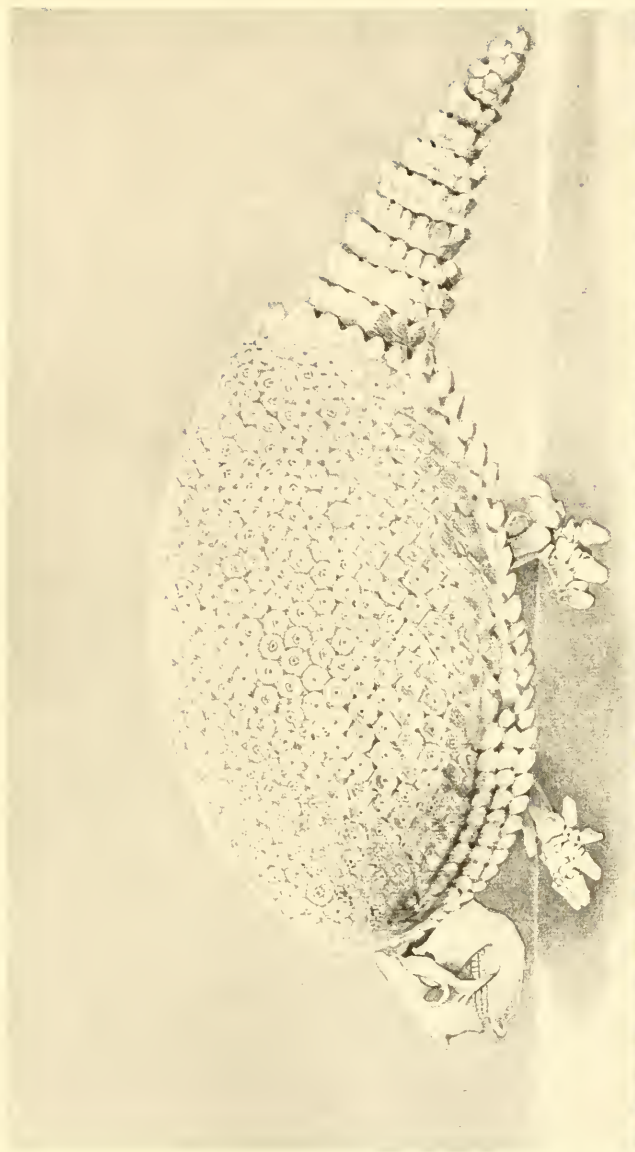
The "blowing" or "spouting" of whales is another subject of widespread misunderstanding. It is popularly supposed that when whales rise to the surface to breathe they pour streams or spouts of water from the nostrils or "blowholes." Nothing of the kind actually happens, however. A whale on rising to the surface merely expels the exhausted air from its lungs with an explosive puff. As this air is warmer than the outside air the moisture that it contains immediately condenses into mist, which is shot upward in a small cloud varying in size and direction according to the kind of whale. Any water that happens to wash over the nostrils at the moment of discharge is also blown into mist and added to the cloud already made by condensation. Sea water in the lungs would be as fatal to a whale as to a man. That whales wounded in the lungs will discharge blood from the nostrils is perfectly true; but any mammal will do the same thing under the same circumstances. Probably the idea that whales spout water from their nostrils comes partly from the popular confusing of whales with fishes.

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A fish breathes the air that is dissolved in water, and everyone has seen fishes apparently swallowing water. What they actually do, however, is to take in water through the mouth and force it out through the gill openings at the sides of the neck after it has passed over the gills. The gills act as lungs, and the blood, in passing over them, obtains oxygen from the air carried by the constantly flowing stream of water. Something entirely different happens in the breathing of a whale or porpoise. Pure atmospheric air must be taken directly into the lungs in order that these mammals may live.

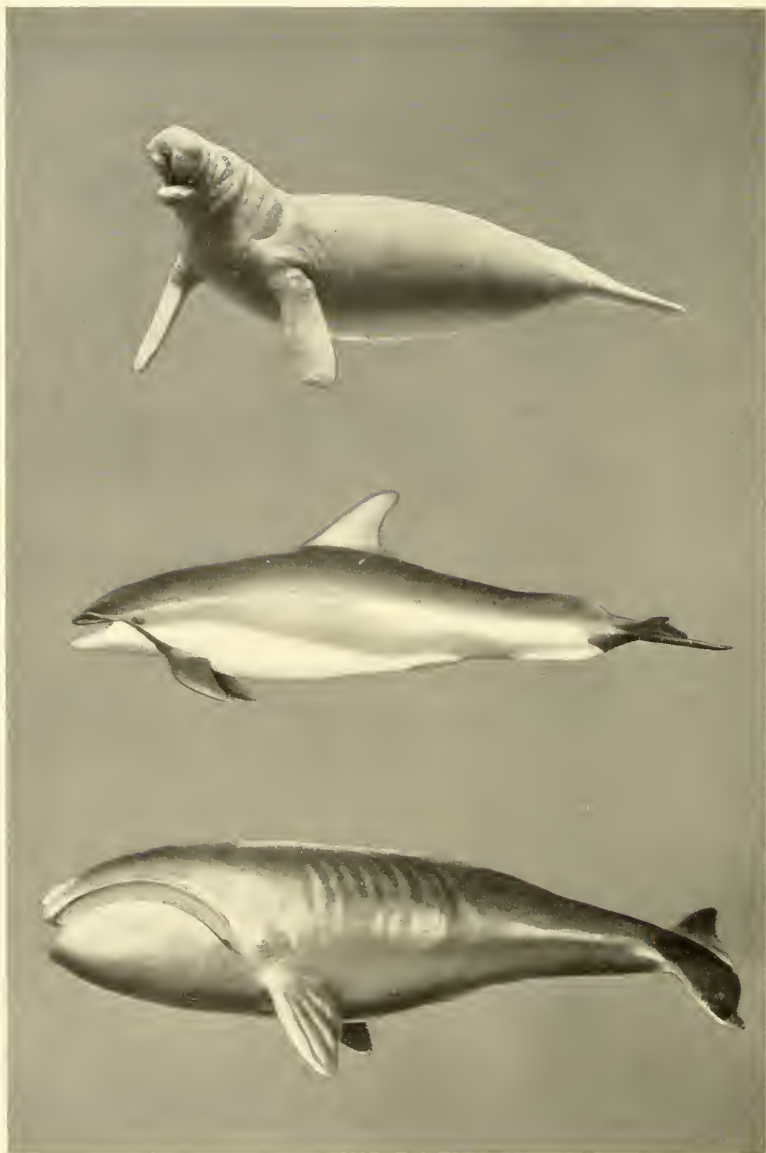
It is commonly supposed that cetaceans form two general groups—whales and porpoises—distinguished principally by size. Such, however, is not really the case. The true distinction lies between the cetaceans that have teeth (with which they capture good-sized fish, squids, and other prey, in the usual manner of predatory animals) and those that have, instead of teeth, many flat horny plates, edged with coarse, bristlelike filaments and growing from the gums in such a way as to form a strainer (by means of which small fish and minute swimming creatures related to shrimps can be obtained in countless numbers). The toothed cetaceans range in size from sperm whales sixty feet long down to porpoises only four to five feet long (Plate 124, middle, and Plate 96). The baleen whales (Plate 124, lower), as those provided with whalebone strainers are called, are mostly large, ranging in length from about twenty feet in the *Neobalaena* of the South Pacific up to 106 feet in the cosmopolitan blue whale, the largest animal positively known to have ever existed either in the sea or on land.

This discussion of the blue whale's size incidentally leads to a question frequently asked in letters addressed to the Smithsonian Institution, namely, "Would it be possible for a whale to swallow a living man?" In answering this question it is easy enough to reply that no authentic observation of such an event has been recorded



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Skeleton and carapace of a glyptodont, *Glyptotherium arizonae*. This extinct relative of the armadillos inhabited Arizona during the late Pliocene. It was about two and a half feet high. Skeleton in the National Museum



Wholly aquatic mammals

Manatee (upper), porpoise (middle), and whale (lower). Not reduced to the same scale. In the manatee, as in all other seacows, the head and neck have not become fishlike, as these members have in the porpoises and whales. Casts and models in the National Museum

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since the study of nature began under modern methods. The difficulty arises when we go farther and try to decide whether the swallowing of a live man might or could actually take place. For we are then brought face to face with two opposed ways of looking at the ordinary happenings in the world we live in. According to one of these ways, the scientific one, the course of everyday happenings in nature is regarded as always regular and undeviating. For example, there is no exception to the rule that sufficient cooling will turn water into ice or that a sufficiently long deprivation of air will kill an air-breathing animal, even a whale. According to the other and more popular way of thinking, the course of natural happenings is conceived of as not always uniform but as having been sometimes turned aside, suspended, or even stopped.

Everyone who regards these natural processes as uniform in their action will, after a little thought, realize that it would be impossible for a human being to live in the mouth of any whale, filled as this mouth is with water, for more than a very few minutes. And when such a person comes to examine the mouths and throats of the two principal kinds of whales he will find other difficulties. For the sperm whale, although it has a gullet wide enough to swallow a man, has a very narrow mouth and a lower jaw armed with such formidable rows of teeth that one bite from them would be sufficient to mutilate a human victim seriously if not immediately to kill him (see Plate 96, page 253). And the difficulty would be no less if a man were taken into the mouth of the toothless whalebone whales. They, it is true, have mouths large enough to hold a man, but their gullets are less than a foot wide—an opening that would barely admit a man's head, not to speak of his shoulders. A slender-bodied penguin, indeed, is the largest prey that any baleen whale has ever been known to swallow; and a man taken into the mouth of one of these monsters would therefore not be able to

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pass on to its stomach at all, and would find his struggles to get out hampered by the great masses of whalebone plates which, together with the tongue, practically fill the mouth. He might escape if the whale remained near the surface with open mouth, but if the animal closed its mouth and "sounded" into the depths the man must almost immediately die. Therefore no one who looks at nature from the scientific point of view can fail to see that the possibility of a whale's swallowing a live man is too remote to be worthy of any serious thought.

On the other hand those who reject the idea that the course of everyday natural happenings is and always has been regular and undeviating are perfectly reasonable in believing that a whale of any kind could, under "suspension of the rules," so to speak, perform the feat of swallowing a man and retaining him unhurt in its stomach for any desired period of time.

Turning now to the different kinds of cetaceans, we find that the whalebone whales are represented by two principal families, the right whales and the finbacks, both of which occur in practically all seas. The right whales—so named because they were the right kind for the whalers to hunt—are distinguished by the great size of the head, which in the "bowhead" or Greenland whale, may constitute two-fifths of the animal's entire length. Not only is the head very long but it is so deep that the whalebone plates, which hang almost vertically from the roof of the mouth, are often as much as eight or ten feet in length. Though formerly abundant, the right whales have now been reduced to the verge of extinction by the indiscriminate slaughter to which they have been subjected.

The finbacks are distinguished from the right whales by the presence of a small upright fin on the back slightly behind the middle. Their heads are broad and flat, so that the whalebone plates in the largest of them rarely, if ever, exceed a length of three or four feet. Among

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the half dozen known species of finbacks is the blue whale, whose enormous size we have already mentioned. Nearly related to the finback is the humpback, distinguished by the replacement of the dorsal fin by a low knob or "hump" and by the very long, slender flippers. Like the finback, the humpback is found in practically all seas. Two other baleen whales, less known than the finbacks and humpbacks, are the California gray whale of the North Pacific and the pygmy whale of the South Pacific. The gray whale is now nearly exterminated. The pygmy whale, whose length is about twenty feet, is too small to be of any economic value. It appears to be a rare animal, and few specimens of it have found their way to museums.

The toothed cetaceans present a greater variety of form and size than the whalebone whales. The largest of them, the sperm whale, certainly attains a length of sixty feet, and longer individuals have been reported. The most extraordinary part of this animal is its head, a drawing of which is reproduced in Plate 96, page 253. The sperm whale's head is unusually large, though not so enormous as that of the bowhead, and it has the unique character of being blunt in front, as if artificially sawed off. This gives the head a form apparently quite unsuited to a swimming animal and certainly very different from that of all other whales. At the back of the skull and at the sides as far forward as the eyes the middle region is depressed and the bony edges are raised so as to form a huge basin, open in front. In this basin and extending out of it forward to the end of the long upper jaw lies a great barrel-shaped mass of fat and oil, held in place by the skin and by strong membranes. It is principally this fatty mass that gives the head its strange shape. As the nostril region of the skull lies deeply buried beneath the mass of fat the sperm whale would be unable to breathe without a tube extending through the fat to the upper surface of the head. Such a tube exists,

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but instead of going to the surface in the shortest way, that is, straight up, it runs obliquely forward to the upper margin of the "sawed-off" snout. Therefore, when a sperm whale "blows," the vapor cloud shoots obliquely forward instead of nearly straight upward, as it does when other whales empty their lungs. Underneath this barrel-shaped head is the long and very narrow mouth. Young sperm whales have at first a complete set of teeth—about fifteen on each side above, and about twenty-five in each half of the lower jaw—but the upper teeth soon degenerate and disappear. The teeth of the lower set, except four or five at the front of each of the two rows, go on growing until they are from six to ten inches long and as thick as a man's wrist. In the region where these teeth are implanted the two halves of the jaw are pressed close together, so that the rows of teeth—twenty-odd in each row—are not much more than a foot apart. Such a jaw, fitting closely into the hard, gristly gums and lips, makes an ideal implement for catching and cutting up the giant squids on which the sperm whale feeds.

Next in size to the sperm whale comes the killers and the beaked whales, animals whose usual length ranges in the neighborhood of twenty to thirty feet. The killers have sets of large sharp teeth in both upper and lower jaws, the teeth of the opposite sets closely interlocking with each other when the mouth is shut. Their large size, great activity, and formidable teeth enable the killers to pursue and capture such animals as seals and porpoises, and to attack in bands the great whalebone whales, like wolves pulling down a horse. Unlike the killers the beaked whales have very few teeth, not more than a pair or two at the end of the jaws or perhaps in the middle. The bones of the long, slender snout form a compact, beaklike mass.

Smaller than the killers and beaked whales but larger than the porpoises proper are the blackfishes and the grampus. These animals are rather heavy-bodied and

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broad-headed. The blackfishes have about twenty teeth—ten above and ten below, but the grampus has only about twelve, all in the lower jaw. The blackfishes are especially remarkable for their habit of going in large schools, which not infrequently become stranded. As many as several hundred of these creatures have been known to perish in this way at one time.

We finally come to the porpoises, or dolphins, the smallest, most active, most diversified, and apparently the most successful of all cetaceans. Usually ranging in size between five and twelve feet and usually provided with a set of from 80 to 140 teeth, the porpoises are perfectly adapted to exploiting the most universally abundant food supply that the sea offers to any mammal, that is, the smaller fish and squids. About fifty different species of living porpoises are known. They inhabit all seas and most of them have very wide ranges. Some of them have dull-brownish or slate-colored bodies, while others have conspicuous markings of dark and light stripes, bars, or spots. All of them are notable for extreme activity and grace. While most porpoises live in the sea, there are some kinds that go far inland up the larger rivers. In a lake of central China there is one kind that appears to be completely landlocked. One that rarely if ever ventures out to sea is found in the Amazon and Orinoco rivers, and another inhabits the rivers flowing into the Bay of Bengal.

Two animals that do not fit into the foregoing rough classification are the narwhal and the white whale, both inhabitants of northern waters. The narwhal is remarkable for the development, usually in the male only, of a tusk or sometimes two tusks, ranging from three to eight feet long and projecting straight forward from the front of the upper jaw. The ivory of which these tusks is formed is spirally twisted; and when there are two tusks the spirals in both run in the same direction, not in opposite directions as is always true of the spirally twisted

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horns of antelopes. Why the male narwhal should ever have a tusk, and why, when he has two, they should be twisted in the same direction, are questions often asked but not yet answered. The white whale is remarkable for its pallid color and for its ability to utter a curious grunting sound while under water, an accomplishment that cetaceans as a rule do not possess.

Fossil remains of cetaceans more or less like the kinds now living have been found in deposits of all ages going back certainly as far as the Oligocene and perhaps to the Eocene. The earliest of these extinct creatures were definitely cetacean, though some of them had the peculiarities of the order less well developed than we see them at present. Hence there is good reason to believe that the beginning of the long process of making over the body of a land mammal into the form of a fish must have been at a period so remote that its probable time can not even be conjectured.

During the Eocene there existed a group of whales or whalelike animals known as the zeuglodonts. They had skulls and teeth quite different in formation from the skulls and teeth of any living cetaceans; and their most extreme line of development led to the building of a slender, probably almost snakelike, body forty or fifty feet long. It has been ingeniously suggested that fugitive glimpses of an elusive survivor of the zeuglodont group may have furnished a real basis for some of the strange stories of "sea serpents"; but at present there is not sufficient reason to take this suggestion seriously.

With the cetaceans we come to the end of our survey of the class Mammalia. While the story has unrolled it seems almost as if we had been watching nature play a game—a game in which the many prizes were chosen from among the multiform opportunities that the world offers for successful animal existence, and in which the rules were: *First*, that a four-footed, warm-blooded body should be made over in every possible way so that there

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might be some kind of mammal to take advantage of every possible opportunity for living; and *second*, that no matter what might be the changes in form of body and in mode of life, or what might be the endlessly varying nature of the adult creature's food—whether it consist of bark, blood, bones, carrion, crabs, eggs, fish, flesh, fruit, grain, grass, honey, insects, leaves, nuts, roots, seaweed, shellfish, squid, or worms—the newly born young must never be fed on anything but mother's milk. And no play in this game appears more bold than the one that brought forward the whales and won the prize of successful life in the sea.

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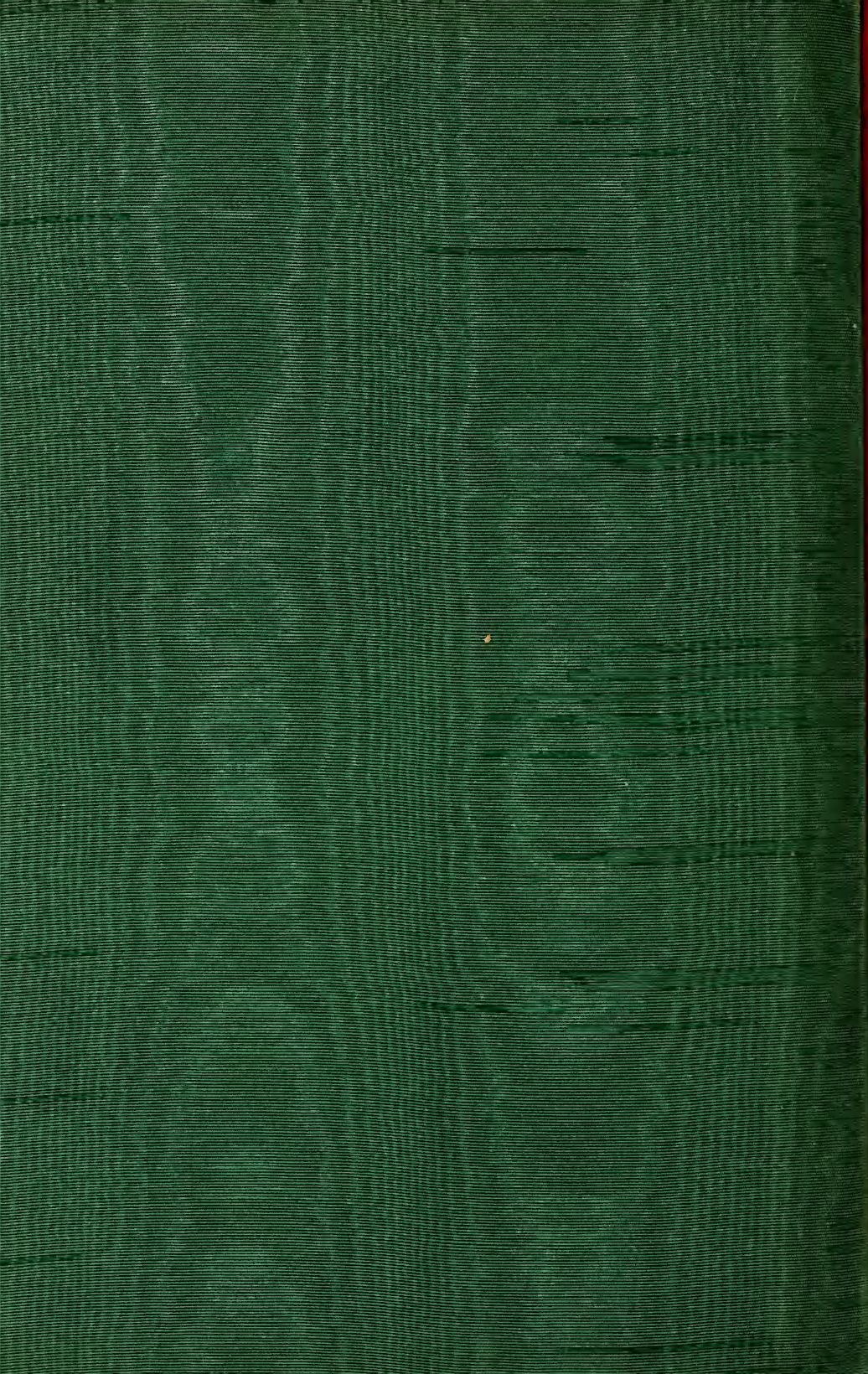
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