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A

HANDBOOK

TO THE CASES ILLUSTRATING

ANIMAL LOCOMOTION.

(WITH ONE PLATE).

1912.

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NOTE.

The section of the Natural History Department which deals with Animal Locomotion has proved to be of such interest and importance that it has been thought advisable to prepare the present handbook in order to present a more connected account of the subject than can be given on the labels in the cases. The Handbook has been written by Mr. H. N. Milligan, F.Z.S., the Zoologist of the Museum; and is edited by the Advisory Curator, Dr. A. C. Haddon, F.R.S.

LAURENCE GOMME,
Clerk of the Council.

CONTENTS.

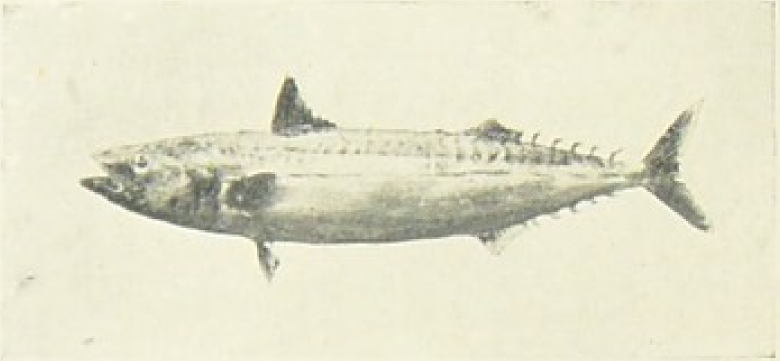
INTRODUCTION.

One of the most obvious characteristics of most animals as compared with most plants is their power of freely moving from place to place. The majority of plants obtain their food from the inorganic materials present in the soil and the air, but animals require as food organic matter which has previously formed part of a plant or another animal. It is important, therefore, that animals should be able to wander freely in order to obtain the food which they need. Facility of locomotion leads to possibilities of development in other directions. An animal which possesses limbs may use them not only for crawling or walking, but for climbing trees, digging burrows, seizing prey, running away from foes, or leaving over-populated areas and seeking fresh ones. It is not surprising, therefore, that of all the parts of the body of an animal those which have to do with locomotion show perhaps the greatest amount of variation in the different groups of animals. Indeed, a study of the way in which an animal moves, and of the structure of the parts by which this movement is effected, provides a source of interest second to none other. It is the object of the Locomotion Series to illustrate the relationship which exists between modes of locomotion and structure in the animal kingdom.

It is important to realise that the different kinds of animals are not immutable fixed forms, but are exceedingly plastic, and that there has been a slow evolution of life upon the earth. We may take as an illustration an imaginary species of a small animal with five clawed toes, which can be used for varied purposes, such as scratching or running or fighting. This animal has the broad general features of its group; it is said to be *generalised*. It is constantly exposed to the attacks of other species of animals and to the competition of its fellows in the search for food, and its environment is in course of change. Under stress of this struggle for existence the habits and structure of its descendants become changed, or the descendants wander into fresh regions and there become adapted to a new life. Some of them may take to the open plains and their limbs become adapted for running; others retreat into the trees and become adapted for climbing; some become burrowing forms; and yet others become adapted for life in marshes or rivers, and finally become purely aquatic animals. Adaptation to a special mode of life may go so far that the animal is practically precluded from following any other, as in the case of the whale, which has become adapted for life in the sea and cannot move upon land ; such an animal is said to be *specialised.* Specialisation may be so extreme that the connection between the specialised descendant and the generalised ancestor would not be suspected in the absence of fossil connecting links between the two. That this imaginary *divergence* of forms has actually occurred in nature over and over again is abundantly proved, and it has occurred on a grand scale on the great continental land masses. It will, of course, be understood that very long periods of time have been occupied in these changes.

As this divergence has occurred in various groups, it thus comes about that numbers of animals derived from totally distinct ancestors have independently assumed not only similar habits but similar forms. For example, the torpedo-like body of a typical fish is the one which allows of motion through water with the least possible resistance ; and in a whale the same form of body has been acquired, although it has been evolved quite independently of the fish. To cases of this kind the term *convergence* is applied (see frontispiece). Convergence is a most fascinating subject, and repeated reference will be made to it in the course of this handbook. It is important that the reader should clearly grasp the meaning of divergence and convergence, as this will facilitate comprehension of the Locomotion Series.

The animals exhibited in this series are grouped under the heads of Swimming, Creeping, Burrowing, Running, Jumping, Climbing, Parachuting, and Flying. They are arranged as far as possible to illustrate the statements made in this handbook. The broader outlines of the subject are dealt with in the large cases (numbered 10 to 44 inclusive, on the west side of the ground floor of the Natural History Hall) and the detailed structural features in the table-cases in the centres of the bays. The locomotion series is complete in itself, but those who desire to make a fuller study of it may also wish to obtain some idea of the relative positions to one another of the various *groups* of animals, and for such students the general " Survey of the Animal Kingdom " on the balcony of the Natural History Hall will be found of assistance. The Museum Library contains a number of works (of which a list will be found at the end of this handbook) touching upon animal locomotion, and these may advantageously be consulted by students.



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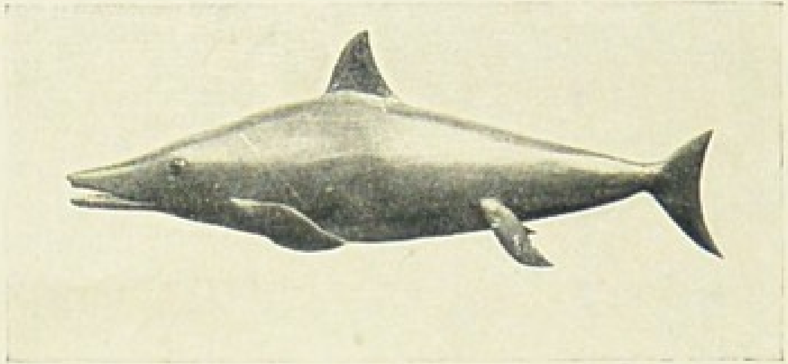

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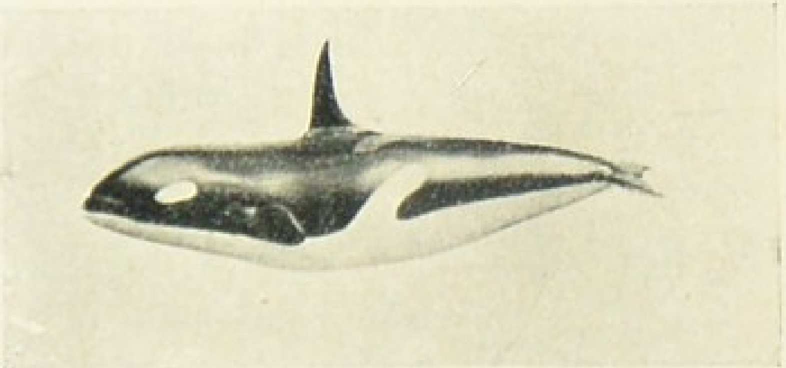

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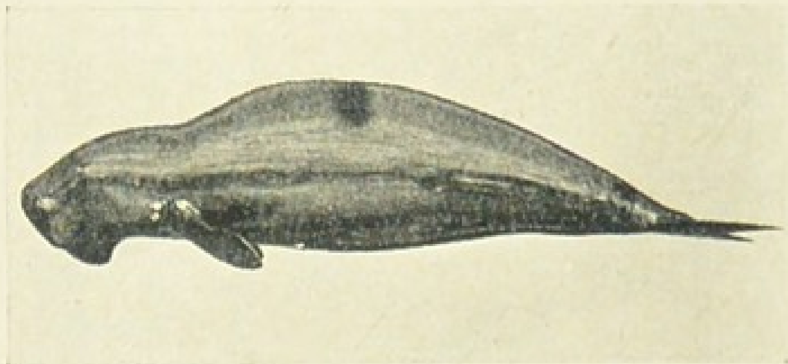

DUGONG.

CONVERGENCE is the term applied to those cases in which the bodily forms of animals not genealogically related tend to resemble one another as a consequence of a similar mode of life. Each of the animals illustrated above, for example, has acquired its torpedo-shaped body, fin-like limbs, and fluke-like tail, in adaptation to an aquatic life quite independently of the others. (See page 6. The photographs are from specimens in the Museum.)

Photos and blocks by the Council's School of Photo-Engraving and Lithography.)

HANDBOOK TO THE CASES

ILLUSTRATING

ANIMAL LOCOMOTION.

SWIMMING.

[Cases 10 to 20 and table-case.]

The sea may be regarded as the probable place of origin of animal life in the past, but whilst many kinds of animals are of purely aquatic descent, others have become re-adapted to life in water after an interval of modification for a terrestrial existence. It is not surprising, therefore, that there should be great variety in the adaptations for swimming found amongst aquatic animals.

PROTOZOA.—Many Protozoa swim by means of *cilia*. The slipper animalcule (*Paramecium caudatum*), a protozoon just visible to the naked eye as a whitish speck and commonly found in large numbers in water containing decaying vegetable matter, is an example. Each cilium is a delicate thread-like process of the animal, and by alternate bendings and straightenings of the whole of the cilia the *Paramecium* swims through the water. Other kinds of protozoa swim by means of *flagella*. A flagellum, like a cilium, is merely a slender process of the body, but the flagellum differs from the cilium in being longer and projecting from the front end of the body; by means of lashing movements it drags the protozoon after it, instead of driving it forward. *Euglena viridis* is an example of a protozoon with one flagellum, *Polytoma uvella* of a protozoon with two flagella.

CŒLENTERATA.—The jelly-fishes, of which *Rhizostoma pulmo* is shown as an example, have usually broad, umbrella-shaped bodies. By rhythmical contractions of the umbrella, water is forced out of the concavity of the umbrella, and by this means the animal is driven along. Jelly-fishes are, however, poor swimmers, and are quite unfitted for making headway against currents or tides. The pulsations of the umbrella may be occasionally observed in specimens of the common jelly-fish (*Aurelia aurita*) which have been left in rock pools by the tide.

ECHINODERMATA.—A mode of locomotion comparable with that of the jelly-fish is found in the rosy feather star (*Antedon rosacea*). Swimming is here effected by alternately bending and straightening the arms, the stroke so given against the water forcing the feather star onwards.

ANNELIDA.—Many annelids are able to swim well. The freshwater leech (*Aulastoma gulo*), swims by means of graceful undulations of the body in the manner shown in the specimen. The animal is able to alter the shape of its body to a considerable extent, and when it is swimming the body is flattened from above downwards, so as to obtain a greater purchase upon the water.

MOLLUSCA.—In the scallops, of which the queen scallop (*Pecten opercularis*) is taken as an example, swimming is effected by rapidly opening and closing the valves of the shell, the forcible expulsion of the water causing the scallop to flit over the sand in a series of jerks. The file shell (*Lima hians*) swims still more effectively through the water by the same method. An interesting parallel is thus afforded to the mode of swimming by water-expulsion which we have already seen in the jelly-fish.

Many cephalopods, represented here by the common cuttle-fish (*Sepia officinalis*) and the squid (*Ommastrephes sagittatus*), also swim by means of expulsion of water, but the adaptation for securing this end is in their case of a much more specialised and effective nature than in the animals already described. In swimming the body lies so that the *siphon** is on the under surface. On this surface is a chamber (the *mantle-cavity*) bounded by a thick muscular wall known as the *mantle*. In this mantle-cavity lie the breathing organs or gills. Water is passed into the cavity through the opening between the body and the mantle, over the gills, and out again through the siphon by contractions of the mantle at regular intervals. By forcible expulsion of the water in jets through the siphon the cuttle-fish can propel itself backwards with great velocity. In order that the water may not escape through the aperture by which it entered, the free edge of the mantle is firmly pressed against the body during expulsion of the water, which is thus forced through the siphon. The mantle carries on each side a knob-like process which fits into a pit upon the body, and by means of these structures the mantle is "buttoned up" during expulsion. It should be noted that the primary use of the current of water through the mantle-cavity is to carry the oxygen contained in solution in the water to

* The siphon and the other parts here mentioned are clearly indicated in the specimen of *Sepia* in the table-case.

the gills for breathing purposes. Its utilisation as a means of rapid locomotion by more forcible expulsion is a secondary adaptation. The fin which runs around the edge of the body probably acts as a balancing organ during swimming.

The octopodes are not such good swimmers as the squids and cuttle-fishes, and they are usually creeping forms. It is interesting to observe, however, that in some cases the swimming mode of life has been resumed. In the octopus known as *Eledone cirrhosa*, for example, the web which unites the bases of the arms is used in much the same way as the umbrella of the jelly-fish to force out the water and to drive the animal along. In *Cirroteuthis* the webbing is much more extensive, and in the deep-sea *Opisthoteuthis* this is carried so far, and the body is so much reduced in size relatively to the arms and web, that the whole animal resembles a flattish disc.

ARTHROPODA.—CRUSTACEA.—In the shrimps and prawns the flattened oar-like abdominal limbs (the "swimmerets") are used for swimming, but a sudden and rapid backward movement is brought about by a vigorous bending of the flattened hinder portion of the body. The tail is first extended straight backwards, and then forcibly bent forwards beneath the body. The lobsters and crayfish are able to dart backwards in the same way. Such a mode of locomotion is of great assistance in enabling these Crustacea to elude enemies, as will be realised by those who have tried to catch shrimps in a rock-pool. In the crabs the reduced abdomen is tucked away beneath the thorax, and walking is the only mode of locomotion practised by most of these Crustacea. It is interesting to note, however, that certain crabs, such as the fiddler crab (*Thalamita natator*), have re-acquired the power of swimming, the last pair of thoracic legs, which are here flattened and oar-like, being used for this purpose. The allied *Polybius* is an expert swimming crab, all the legs being flattened.

INSECTA.—The common water-beetle (*Dytiscus marginalis*) may be taken as an example of a swimming insect. The boat-like shape of the body, with its sharp edges and smooth surface devoid of any projections, is beautifully adapted for cleaving the water. The legs, which are the propelling organs, lie in the middle of the length of the body where this is thickest, and hence where they will be able to exert the greatest propelling power. The foot is lengthened and flattened, and it can be rotated in such a way that during the forward movement its narrow edge is directed forwards to cleave the water, and during the backward movement its flat surface is directed backwards to obtain as much purchase upon the water as possible. The two legs are use simultaneously in swimming. An enlarged model of a swimming leg of *Dytiscus*, together with a model of an ordinary running type of leg, such as is found in *Carabus*, will be seen in the table-case. Living water-beetles can usually be seen in the aquaria in the corridor.

VERTEBRATA.—CEPHALOCHORDATA.—The lancelets are small fish-like animals of about one to two inches in length, which are found in the shallow seas of many parts of the world. They may be regarded as primitive and in some respects degenerate vertebrates. *Amphioxus lanceolatus* is here shown as an example. Its body is stiffened by a firm yet flexible rod, known as the *notochord*, which runs along the body from one end to the other and serves to straighten the animal after it has been bent to one side. By alternately bending the body, first to one side and then the other, an undulating swimming movement is produced.

CYCLOSTOMATA.—In the lampreys and hag-fishes the axial rod of the body is strengthened by a rudimentary vertebral column which surrounds the notochord, but it is still elastic and the animal swims by lateral undulatory motions of the body.

FISHES.—The organisation of a true fish such as the mackerel (*Scomber vernalis*) shows a distinct advance upon that of the lancelets and lampreys in its adaptation for swimming. Fins are highly developed, and exercise most important functions. The body is smooth and torpedo-shaped, with a wedge-like head, and this form is the one best adapted for rapidly and easily cleaving the water. The tail and tail- (or *caudal*) fin together act as a powerful propelling organ, and the other fins act as guiding, stopping, turning and, to a less extent, as balancing organs.* When the fish wishes to stop quickly the *pectoral* fins, which in forward swimming are usually held flat against the sides, are suddenly extended at right angles to the body, and this causes a retardation of the forward movement. Extension of only one pectoral fin causes the fish to turn, as it swings round this fin as a fixed point. The fins which lie along the middle line of the back act as a keel to steady the body, and the anterior edge of the front one acts as a cut-water. The *posterior dorsal* and the *anal* fins are probably also accessories of the tail, and assist it in obtaining a greater purchase upon the water. An *air-bladder* is found in the body-cavity of most fishes. Its principal function is to render the fish of the same weight, bulk for bulk, as the water,

* The actions of the tail and fins in swimming may be watched in the living fishes of different kinds in the Museum aquaria.

so that the fish possesses the advantage of being able to move about rapidly with the minimum expenditure of energy. In many kinds of fish the form of the body differs greatly from that of the mackerel. In the sea-horse (*Hippocampus antiquorum*), for example, the tail is devoid of a caudal fin and is used for grasping the sea-weeds amongst which the sea-horse lives, and swimming is effected by rapid vibrations of the small dorsal fin, the animal having a vertical position in the water, as shown in the specimen. The body of the eel is greatly elongated, and the animal simply wriggles through the water by means of lateral undulations of the body, the tail being flattened from side to side. The eel has an apparent resemblance to the lampreys, but it is really a true fish, whose body has been modified in adaptation to a mud- or gravel- inhabiting mode of life. In the skates, which are allied to the sharks, the body is greatly flattened from above downwards, the sides being formed by the greatly extended pectoral fins. By up-and-down undulations of these fins the skates flap their way through the water. The plaice (*Pleuronectes platessa*) and the sole (*Solea vulgaris*) are also flattened, but from side to side instead of from above downwards, and these fishes swim by undulations of the whole body from back to front. In each case the flattening of the body serves the same purpose, that is, it is an adaptation to a bottom-feeding mode of life, and may be also an adaptation for concealing the fishes from enemies when they are lying upon the sand of the sea bottom; but it has been brought about in each in a quite different manner, the skate being, as already pointed out, flattened from above downwards, the plaice from side to side. This conformation of the body has resulted in fresh adaptations for swimming in these fish.

AMPHIBIA.—Most amphibians are equally at home on land or in water, whence their name*. The newts swim mainly by means of the large, strong, and laterally flattened tail, which, together with the body, is undulated in the manner shown in the specimen of the common great crested newt (*Molge cristata*). In the three-toed salamander (*Amphiuma means*) the limbs are small and feeble, the toes being reduced to two or three in number, and swimming is effected by wriggling in an eel-like manner through the water. The form of the body is very eel-like; but it will, of course, be understood that the resemblance between *Amphiuma* and the eel is merely superficial and due to both animals having been modified for the same mud-inhabiting mode of life. The frogs, as is well-known, are entirely aquatic in the young

* Greek, *amphi*, on both sides; *bios*, life.

(" tadpole ") stages, and swim like the newt by means of their large tails, but the adults are tailless, and the greatly developed hind limbs are used in terrestrial locomotion by jumping. Swimming is, however, well performed by vigorous backward and outward strokes of these legs, as in the specimens of the bull frog (*Rana catesbiana*). The toes are elongated and webbed in order to offer as large a surface as possible to the water.

REPTILIA.—Amongst the group of reptiles which includes the tortoises and turtles there are many kinds which are almost entirely aquatic, and some of them exhibit a high degree of specialisation for swimming. The shell, which is high and vaulted in the land-tortoises, is levelled down, in adaptation for swimming, in forms such as the river-haunting soft tortoise (*Trionyx triunguis*). The toes, too, are webbed in these aquatic forms. The edible or green turtle (*Chelone mydas*) is entirely marine, resorting to the shore only for the purpose of laying eggs, and the limbs are modified into flattened paddles. From this we are led on to the most highly specialised of all living turtles, the leathery turtle (*Dermatochelys coriacea*). In this animal the portion of the shell known as the *plastron*, which covers the ventral surface of the body, is not so well developed as in ordinary turtles. The dorsal portion of the shell (the *carapace*), again, is quite free from the underlying ribs and backbone, to which it is fused in ordinary turtles. Certain extinct leathery turtles had the carapace reduced to a few marginal bones, and from all these facts it may be inferred that the leathery turtles have been derived from true turtles by a gradual reduction of the shell. Claws, also, are entirely absent in the leathery turtle, while in the less specialised green turtle there is but one claw on each foot, and in the soft tortoise three claws on each foot.

The most highly specialised swimming reptiles were the extinct mesozoic " fish-lizards " or ichthyosaurs, of one of which a reduced restoration is shown in case 13. Externally, the ichthyosaurs must have much resembled the present-day porpoises, whose place they took in the mesozoic seas. The fish-like form of the body, the very short neck by which the head merges into the body, the paddle-like limbs and the fluke-like tail all demonstrate the essentially aquatic nature of these reptiles. That the ichthyosaurs were derived from land reptiles is certain, and the fish-like form is to be looked upon simply as an adaptation to the same environment to which the fish has become adapted. Examination of the skeleton of the ichthyosaur at once reveals the reptile. In the fish and the ichthyosaur we have a most striking instance of convergence, and additional interest is lent to the subject upon observing that in yet a third group (viz., the whales, amongst the class of Mammals) adaptation to an aquatic life has resulted in a fish-like shape; and in certain other groups (Plesiosauria among Reptiles, Sirenians and Seals amongst Mammals) there is a marked approximation towards this shape.

Many lizards are excellent swimmers. The monitor (*Varanus salvator*) has a long laterally flattened tail which is used as an oar and rudder, the legs being held flat against the body, as shown in the specimen. In the basilisk lizard (*Basiliscus galeatus*), on the other hand, the fore-limbs are used in swimming and the long crested and rudder-like tail is dragged behind, whence the name of ferrymen often applied to these lizards. The Galapagos sea-lizard (*Amblyrhynchus cristatus*) frequents the sea-shore and, like the monitor, swims by means of its flattened tail.

A laterally flattened tail is also present in the crocodiles and alligators, which are essentially aquatic animals, and swimming is assisted by the hind legs. In these animals there are some interesting modifications for aquatic life. It will be observed that the external openings of the nostrils are situated upon the upper side of the end of the snout, that is, in the position in which they can be most readily brought into use when the animal wishes to breathe without exposing itself above the water. The internal opening of the nostrils is placed far back in the pharynx, immediately over the upper end of the wind-pipe, and can be cut off completely from the mouth by means of membranous folds. Owing to this arrangement a crocodile is able to keep its mouth wide open under water and drown the prey which it has seized while carrying on its own breathing at the same time.

Many snakes are amphibious, but certain kinds are almost entirely aquatic. The wart snake (*Chersydrus granulatus*) is not only an inhabitant of the mouths of rivers, from Southern India to New Guinea, but is frequently found far out at sea. Its body and tail are markedly flattened from side to side; and the same modification occurs in other species, such as the sea-snake (*Pelamis bicolor*). In the banded sea-snake (*Platurus colubrinus*) the body is not only flattened, but the tail is oar-like.

BIRDS.—The aquatic birds are contained in cases 19 and 20. The water level is indicated by sheets of thin glass, and all the birds at this level are shown in the act of swimming upon the surface; those beneath are shown in the act of diving and swimming under water. While many birds are merely occasional surface swimmers (for example, the gulls), others are perfectly at home when diving and swimming beneath the water (examples, the shag and penguin), and a series of gradations between these extreme types may be traced. Most aquatic birds possess certain characters in common. The oil-gland situated upon the rump is large, and the oil secreted by it, which is used by most birds in preening the feathers, is copious. The oil prevents the feathers from getting wet, and the air is consequently not displaced from between them, so that the skin of the bird is kept dry and warm. Indeed, the facility with which the water is shed off the oily plumage of the duck has become proverbial. Fat is also usually accumulated beneath the skin and assists in keeping the body warm. Again, the feet of aquatic birds are usually more or less webbed.

It should be understood that during the course of evolution, different groups of birds have independently acquired aquatic habits. The ducks, for example, have evolved into surface-swimming types, independently of the gulls; and the razor-bills, puffins, and their allies into diving forms apart from the penguins.

The gulls have already been mentioned as occasional surface swimmers. Locomotion is effected by a paddling action of the feet. In the ducks, which are more highly specialised for swimming, the feet are placed further back under the body, in order to increase their propulsive power, and it is this backward position of the feet which gives the duck its peculiar waddling gait upon land. The same observation may be made upon the diving birds, such as the shag (*Phalacrocorax graculus*), cormorant (*Phalacrocorax carbo*), gannet (*Sula bassana*), darter (*Plotus melanogaster*), pelican (*Pelicanus fuscus*), crested grebe (*Podicipes cristatus*), and great northern diver (*Colymbus glacialis*). Indeed, in the great northern diver walking is performed with such difficulty that the female builds her nest close to the water so that she may instantly slide into the water when alarmed. All the above-mentioned birds swim by means of the feet, but in the auks, represented here by the puffin (*Fratercula arctica*) and the black guillemot (*Uria grylle*), the wings are employed as swimming organs, the feet being chiefly used as rudders. In spite of their adaptation to this kind of locomotion, auks retain the power of flight. In the penguins, however, in which the extreme of modification for an aquatic life is reached, the wings are wholly transformed into stiff paddles and are useless for flight. The short feathers are scale-like and form a smooth close-fitting investment for the body. The feet are placed further back than in any of the types so far examined, and the bird in consequence assumes an almost upright attitude when on land, as may be seen in the specimen of the jackass penguin (*Spheniscus magellanicus*) standing upon the ledge of rock at the back of the case. The feet are used mainly as steering organs during swimming. In birds which fly in the air the stroke of the wing during flight is directed downwards and forwards, as will be subsequently explained, but in the penguins the wing is so placed relatively to the body that the swimming stroke is directed downwards and backwards.

MAMMALIA.—It is well known that almost all mammals, even such heavy animals as cattle, are able to swim when compelled to take to the water, as the walking movements ordinarily employed on land closely resemble those which are required in swimming.* Many mammals are, however, especially adapted for an aquatic life ; some of them, indeed, are so specialised for swimming that they are unable to move upon land. Between those which merely resort to the water occasionally and those which live entirely in that element a regular series of gradations may be traced. Swimming mammals may be conveniently classified as follows :—

1. A group whose members, while able to swim freely, are not especially adapted for swimming. Examples are, the common brown rat (*Mus decumanus*) and the aguti (*Dasyprocta aguti*).

2. A group whose members are equally at home on land or in water. One or both pairs of feet have the toes more or less webbed, and the tail is sometimes modified into a paddle, which is flattened either from above downwards or from side to side. Examples, the mink (*Mustela lutreola*), otter (*Lutra vulgaris*), common water-vole (*Microtus amphibius*), musquash (*Fiber zibethicus*), desman (*Myogale moschata*), beaver (*Castor fiber*), potamogale (*Potamogale velox*), and the duck-bill (*Ornithorhynchus anatinus*).

3. An almost entirely aquatic group, in which adaptation to an aquatic life has advanced a step further. The body approximates to the fish-shape, and the feet are modified into flippers. The seal (*Phoca vitulina*) is an example of this group.

4. A wholly aquatic group in which the approximation to

* The erect posture of a man is so different from that of most animals that he experiences difficulty in assuming the horizontal position and moving his limbs in the appropriate manner when making preliminary attempts at swimming.

the fish shape is most marked. The body is smooth and hairless and the tail forms a swimming " fluke." Examples, the dugong (*Halicore dugong*), the Greenland whale (*Balæna mysticetus*), the sperm whale (*Physeter macrocephalus*) and the killer whale (*Orca gladiator*).

It will be understood that this is merely a convenient artificial classification. There are many connecting links between the groups, and it is often difficult to decide where one group ends and another begins. From a study of such a series, however, we are able to gain some idea of the probable steps by which a purely terrestrial mammal has evolved into an aquatic one. There can be no doubt that all mammals were originally terrestrial, but most terrestrial mammals can swim when necessary, and it is easy to imagine that in those forms which took more and more to swimming, successive adaptations to an aquatic mode of life were acquired, such as webbed toes, flattened tails, smooth fur, and small external ears. Then in the more advanced forms the feet became modified into flippers, and finally hair was almost entirely lost, as were also the hind limbs, the tail became formed into a fluke, or paddle, and the animal became quite incapable of moving upon land. By such a study we are also able to see more clearly how numerous have been the cases of convergence among mammals. For example, in the musquash (which belongs to the order Rodentia) and the potamogale (which belongs to the order Insectivora) the tail is flattened from side to side ; in the otter (Carnivora), beaver (Rodentia) and duck-bill (Monotremata) the tail is flattened from above downwards ; in the dugong (Sirenia) and the whales (Cetacea) the hind limbs have disappeared, the front limbs form balancing and steering paddles and the tail forms a horizontal fluke or propellor.

Whales are so completely adapted to an aquatic life, and their shape is so fish-like—the torpedo shape, it will be recollected, being the one best adapted for rapid progression through water—that they are commonly, but of course quite incorrectly, looked upon as fishes. Unfortunately, little or nothing is known of the early mammals from which they must have taken their origin. It may be useful to point out that the possession of lungs is a sufficient indication of the descent of whales from land animals ; for if they had descended directly from fishes, there would have been no necessity for the whales to acquire lungs, and the fish-like mode of breathing by gills would have been retained. As it is, whales are compelled to ascend to the surface periodically in order to breathe. As already pointed out, whales are practically hairless, but the hair (which would tend to retard rapid movement through water) is functionally replaced by a thick layer of oily fat, known as "blubber," which lies beneath the skin and serves to keep the body warm. The head passes into the body without the intervention of a distinct neck, so that the front portion of the animal forms a wedge-shaped mass well adapted to cleave through the water, and this is a feature which has been already noted in the fishes and ichthyosaurs. A few small bones hidden in the body indicate the former possession of hind legs. An important feature of whales is that the external openings of the nostrils lie far back upon the upper surface of the head, an arrangement which allows of the animal taking breath immediately its head reaches the surface (see skulls in table-case). The flukes of the tail have a screw-like form, one half being convex upwards, the other half concave, and the tail is said to be used in a somewhat screw-like manner. The horizontal position of the flukes of the tail enables the animal to rise quickly by a few strokes to the surface for breath. In a fish the tail-fin, which drives the animal straight forward, is vertical.

CREEPING.

[Case 21 and table-case.]

Creeping animals are here taken to be such as are able to move along a firm surface without the aid of paired jointed limbs of the type found, for example, in the lobster, lizard, or dog. It is, however, difficult to define creeping animals, as they merge into walking animals on the one hand and climbing animals on the other. As might be expected, creeping animals belong for the most part to the more primitive and lowly groups although certain vertebrates, the snakes and legless lizards, have reverted to it as a secondary mode of locomotion.

PROTOZOA.—The amœba (*Amœba proteus*) is a common protozoon found in fresh-water ponds and damp places. It is an irregular mass of protoplasm, of about one hundredth part of an inch in diameter. Its most characteristic feature is its constantly changing shape, blunt finger-like processes (known as *pseudopodia*) being continually produced, now in one direction, then in another. The formation of a pseudopod is initiated by a bulging of the periphery of the animalcule, then the bulging increases in size, and finally a portion of the more fluid part of the protoplasm flows rapidly into the process. Continued production of pseudo podia in one direction leads to movement in that direction, although the movements are seldom performed in such a way as to lead to definite continued progress; frequently pseudopodia are produced in several places at once, and the amœba then may follow the largest. This kind of movement is called *amœboid.* It should be observed that the amœba, like other simple protozoa, corresponds merely to one of the units (or *cells*, as they are called), comprising the bodies of other animals, and, therefore, the pseudopodia cannot strictly be called limbs. In such protozoa as have a firm envelope to the cell, protrusion of pseudopodia is, of course, not practicable, but in many cases fine filaments are protruded permanently through the wall, and by lashing movements propel the protozoon along through the water. Such filaments have already been referred to under the names of cilia and flagella (page 7).

ECHINODERMATA.—A most interesting and curious mode of locomotion is practised by the starfishes. A starfish walks by means of numerous tube-feet (*ambulacra*), which lie in a groove running along the mid-ventral surface of each arm. A tube-foot is a soft flexible organ, whitish in colour, and with a flat disc at its end. When the starfish is walking the disc is pressed upon the ground, and its central portion is then raised, so that the foot adheres firmly, just as a leathern sucker does when it is pressed upon the pavement and its centre raised by means of a string. By stretching out its tube-feet and alternately fixing and releasing them the starfish is able to ascend vertical surfaces. The tube-feet are hollow, and their cavities are in communication with a system of fluid-filled canals, the whole arrangement constituting the *ambulacral system.* The movements of the tube-feet are brought about partly by the squeezing of this fluid into them, and partly by muscular action. The arrangement of the ambulacral system is illustrated by means of diagrams and specimens in the "Survey." The mode of walking may also often be watched in the living starfishes in the Museum aquaria, the best time to study it being when the animals are climbing up the glass fronts of the aquaria. Other echinoderms, such as the sea-urchins and sea-cucumbers, walk by means of tube-feet. In the globular sea-urchins, however, the tube-feet have more difficulty in pulling the animal along than is the case in the flattened starfish in which the whole or nearly the whole of the body rests upon the tube-feet, and is therefore easily moved. This difficulty is overcome by the aid of the spines, each of which is attached to the body by a ball-and-socket joint. One or more tube-feet are extended, fixed to the ground, and then contracted, so that the animal is pulled forward. The few spines which are in contact with the ground then act as so many fixed points, over which the body swings at the ball-and-socket joints. The sea-urchins are typically spheroidal in shape, the common edible urchin (*Echinus esculentus*), for example; but some kinds of sea-urchins have become somewhat elongated along one axis, so that they have a superficial resemblance to an ordinary two-sided animal. This latter *bilateral symmetry* is found amongst urchins which live on and in the mud of the sea bottom, and is associated with constant movement in one direction. In the globular urchins the mouth is in the middle of the ventral surface and the anus on the upper surface; but in those urchins which have become bilaterally symmetrical, the body has not only become elongated, but the mouth has moved near to what is now the front end of the animal, and the anus to the under surface of the hinder portion. The common *Echinocardium cordatum* and *Spatangus purpureus* are examples of sea-urchins with this superimposed bilateral symmetry.

MOLLUSCA.—Snails and slugs are typical creeping animals. The ventral portion of the body forms a large muscular mass, known as the *foot*, upon which the animal creeps. Land snails pour out from a gland in the foot a slimy secretion which enables the animals to glide over the surface upon which they are creeping, and it is this secretion which produces the familiar glistening trail left by a snail. The snail advances by a series of waves of muscular contraction and expansion which flow over the whole foot from behind forwards, at the rate of 30–50 per minute. The foot undergoes many modifications in the molluscs. In the snails and slugs it is a creeping organ, in certain marine molluscs such as *Carinaria* it is a swimming organ, in the razor shells it is a burrowing organ, and in the octopus and its allies it is not only a creeping but also a seizing organ. The common octopus (*Octopus vulgaris*) represents the last mentioned group. The foot is believed to have extended forwards in the course of evolution, fused intimately with the head, and developed long tentacles, provided with numerous suckers.* The suckers are primarily seizing organs by which prey is captured, but in the octopodes they are also used for creeping. Some of the tentacles are extended forwards, as in the specimen shewn, made fast to the ground by their suckers, and then contracted, so that the animal is dragged forward.

* Whence the name of the group to which the octopus and its allies belong, the Cephalopoda, or "head-footed" animals.

VERTEBRATA.—REPTILIA.—The snakes are of all animals the most highly specialised for creeping. The slender body is greatly elongated and limbs are absent. It is known that snakes are descended from reptiles which possessed the usual four limbs, and their bodily shape is an adaptation to enable them to glide easily and readily amongst trees or through crevices in rocks, or amongst grass and thickets, so that they may escape quickly from enemies, and also elude observation. Under such circumstances limbs would be not only useless but a positive hindrance, and in the course of evolution they have disappeared.* The limbs have been functionally replaced by the ribs, which are very numerous, and attached to the backbone in such a way that they have a wide range of motion. Speaking of the locomotion of snakes Dr. Günther says : " Although the motions of snakes are in general very quick, and may be adapted to every variation of ground over which they move, yet all the varieties of their locomotion are founded on the following simple process. When a part of their body has found some projection of the ground which affords it a point of support, the ribs, alternately of one and the other side, are drawn more closely together, thereby producing alternate bends of the body on the corresponding side. The hinder portion of the body being drawn after, some part of it finds another support on the rough ground or a projection, and the anterior bends being stretched in a straight line, the front part of the body is propelled in consequence. During this peculiar kind of locomotion, the numerous broad shields of the belly are of great advantage, as, by means of the free edges of those shields, they are enabled to catch the smallest projections on the ground, which may be used as points of support. Snakes are not able to move over a perfectly smooth surface." The shields here mentioned may be seen in the exhibited specimen of the common grass snake *Tropidonotus natrix*), which is shown in a creeping attitude. The number of joints in the backbone is very large, and in order to guard against dislocation of the spine during the complicated twining movements performed by snakes, the segments (*vertebræ*) are joined together by an unusually complicated system of articulations. It will scarcely be necessary to point out that snakes, far from being the degraded animals they are sometimes hastily assumed to be, are, as a matter of fact, very highly specialised animals.

Lizards have typically four limbs, and it is therefore in-

* In the boas and pythons and some allied forms two claw-like projections, supported by small bones, remain to attest the former presence of hind limbs.

teresting to find that certain of them, the common "slow-worm" (*Anguis fragilis*), for example, have assumed the creeping mode of life and are without external limbs; indeed, their appearance is so snake-like that they are very commonly mistaken for serpents. Like snakes they walk upon their ribs, although they are not so highly specialised for creeping.

BURROWING.

[Cases 22 and 23, and table-case.]

There are many advantages in a burrowing mode of life. For example, the animals which adopt it are not only enabled to retreat beneath the surface of the soil in order to escape from foes when occasion requires, but many of them there seek food which, if somewhat scanty, is practically out of the reach of other animals and can be obtained with a large measure of safety. In the case of animals which burrow in the sand of the sea-shore, protection is obtained against the wash of the waves, as well as against the attacks of foes. Such animals are also kept moist, and this is very important in animals which would be fatally injured if their delicate gills or skin became dry. Again, some animals have adopted burrowing not only in order to obtain safety for themselves, but in order to prey upon other burrowers, like the mole, which preys upon worms. One important advantage is the security with which the young can be reared in underground nests; the rabbit will serve as a familiar example. As might be expected, burrowing animals are all of relatively small size, and are usually weak and helpless.

ANNELIDA.—The earth-worms are familiar burrowing animals. The elongated body is divided into a number of successive segments, the division between each segment being indicated externally by a transverse groove. Nearly all the segments bear *setæ*. There are four setæ on each side of each segment, arranged in two pairs, so that examination of a worm reveals two double rows of setæ running along each side of the body. Each seta is a short bristle which projects outwards and backwards from the body. The setæ are too fine to be seen without the aid of a lens, but they can be felt when a worm is drawn through the fingers from tail to head. The anterior portion of the worm being extended in the required direction, the setæ act as so many anchors to hold that part while the hinder portion of the worm is drawn forward. This results in the characteristic locomotion of a worm with which all are familiar. The use of the setæ as anchors may easily be demonstrated by the above-mentioned operation of drawing a worm through the fingers from tail to head, or by endeavouring to pull a worm out of the ground into which it has thrust the first portion of its body. If the worm be felt from head to tail it slides through the fingers, as the smooth slimy skin and backwardly projecting setæ offer no resistance. Muscles are attached to the inner portion of the setæ so that the latter can be moved at will. This is very important in an animal which has to withdraw rapidly backwards into a narrow burrow. In such circumstances the setæ are withdrawn into the body. The worm pushes its way through the soil with its tapering anterior end when burrowing, but as it is constantly swallowing soil and passing it through its intestine in order to obtain nutriment from the decaying animal and vegetable matter which the soil contains, the worm may almost be said to eat its way through the earth. The earth which has been passed out of the intestine is often to be seen upon the surface of the soil, where it takes the form of long coiled masses, known as "worm castings."* The burrow usually ends in a small excavated chamber lined with small stones. The mouth of the burrow is guarded by small stones, or leaves which have been dragged into it by the worm.

ARTHROPODA.—INSECTA.—The mole-cricket (*Gryllotalpa vulgaris*) is one of the most highly specialised of all burrowing insects. This cricket derives the first half of its name from the general resemblance of its front legs to the hands of a mole, and its subterranean habits. The front legs are highly specialised digging organs. The short, broad tibia has four large, hard teeth, and is used in digging, after the manner of a spade. The terminal tarsal joint bears two spines, which are probably used in cleaning the spade when it has become clogged with earth. The animal digs out the earth with simultaneous outward movements to right and left. Considerable force is used in these movements, and it has been recorded that a mole-cricket has thrust away two weights of three pounds apiece in this manner. A greatly enlarged model of this limb will be found in the table-case, and it should be compared with the more ordinary type of insect leg exemplified by the leg of the running beetle *Carabus* beside it.

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* Readers who may wish to obtain further information upon this subject are referred to Darwin's "The formation of vegetable mould through the action of worms," a copy of which is in the Museum library.

MOLLUSCA.—In an ordinary bivalve mollusc such as the common freshwater mussel (*Anodonta cygnea*) the foot is somewhat hatchet shaped, the two openings at the hinder end of the body for the entrance of water and the exit of waste matter are provided with marginal fringes, and the shell is oval in shape (see table-case). In a bivalve specialised for burrowing, such as the sand gaper (*Mya arenaria*) the shell is more or less elongated from back to front, as a narrow shell can be more readily withdrawn into a burrow; the foot is placed far forward in the most effective position for making a burrow through which the rest of the body can easily follow; and the two fringed openings already referred to in Anodonta are elongated, so that their open ends can be extended up to the mouth of the burrow to carry on their functions while the animal itself is hidden in the sand. In the razor shell (*Solen ensis*) specialisation is carried a step further; the foot is quite at the front end of the animal, and the shell is greatly elongated and narrow. The foot in the razor shell is unusually long when fully extended, and during burrowing its end is caused to swell by means of the blood which is pumped into it, thus forming an anchor by which the animal holds firmly until the remainder of the body is dragged onwards. When a razor shell is alarmed it retreats into the burrow so rapidly that it is difficult to capture it, even by thrusting a spade quickly into the sand beneath it. In ordinary bivalves the two valves of the shell fit closely together when closed, but in the razor shell, as in many other of the more highly specialised burrowing forms, the valves have such a form that they permanently gape open at the places where the foot and the siphons are thrust out. The reason for this is, that the animal would find it difficult, or perhaps impossible, to separate its valves in its narrow burrow each time it protruded the foot, and when separated the infiltration of sand between the valves would be an inconvenience.

VERTEBRATA.—AMPHIBIA.—The worm-like amphibians known as cœcilians are burrowing animals, living in mud or soft soil. The eyes are either absent or vestigial, and in all cases the animals are blind. It may here be pointed out that eyes are not only of little use to a subterranean animal, but may even be a source of danger, on account of their liability to injury, and it is not surprising, therefore, that in the more highly specialised burrowing types of all groups there is a tendency to reduction and loss of eyes, as will be seen in the following accounts. The head is solid and compact in the cœcilians, and this is an adaptation enabling them to push their way through yielding soil. Limbs, unless they are to be used in digging, would be in the way in a burrowing animal, and they are entirely absent. It is certain that the cœcilians are descendants of amphibia with limbs, and the loss of limbs is to be regarded as another adaptation to a subterranean life.

REPTILIA.—Lizards are typically animals with four limbs, but in certain burrowing forms the limbs have become reduced, or even disappeared. The amphisbæna (*Amphisbæna fuliginosa*) is an example of the latter. The body in the amphisbænas is elongated and snake-like, the head is unusually solid and compact, and the eyes are vestigial. In these features the reader will not fail to note the convergence between the cœcilians and amphisbænas. Amphisbænas are able to move backwards or forwards indifferently, and this is of great assistance to them, as a burrowing animal has frequently to move rapidly backwards through its burrow.* It is interesting to note that in one genus of amphisbænas, *Chirotes*, there are still small fore limbs.

The shape of the body in snakes and its adaptation to creeping has been already described (page 20). In the blind snakes (represented in the collections by *Typhlops vermicularis*) which are almost entirely subterranean, the large transverse ventral scales which we saw to be so characteristic of ordinary snakes are absent, and their place is occupied by numerous small, smooth, close-fitting scales similar to those which invest the remainder of the body, and these oppose no obstacle to easy movement through the soil. The head is smooth and compact and the vestigial eyes lie beneath the skin.

MAMMALIA.—There are many kinds of burrowing mammals, and many gradations in specialisation for this mode of life, from the rabbit, which scratches out a burrow in the soil into which it can retreat and bring up its young in safety, to the mole, which lives almost permanently underground.

The common mole (*Talpa europæa*) is selected for special description, as it is not only a familiar animal and one easily obtainable, but is highly specialised for burrowing. The body is cylindrical,† and the conical head passes without any distinct neck into the trunk. The body is thus wedge-like, a form which enables the mole readily to push forward

* This habit, as well as the difficulty in immediately distinguishing the head from the tail, has given rise to the popular misconception that the amphisbænas are two-headed snakes. Their name is derived from the Greek *αμφις*, both ways, *βαινειν*, to go.

† The following details may be verified from the preparations in the table-case.

through yielding soil. The fore limbs are short and powerful, and the under surface of each broad foot is directed outwards and backwards to act as an efficient digging instrument. The toes of this foot bear strong claws which assist in loosening the soil during digging, and a strong curved bone lying to the inner side of the first digit serves to increase the expanse of the foot. The thick and powerful fore limbs are placed further forward than in ordinary mammals so that they are brought beside the neck, and this is a very important adaptation in an animal in which any projecting portion of the body would retard rapid movement through narrow subterranean tunnels. Again, this forward position of the limbs enables the mole to thrust its feet forward beyond the snout when digging. The eyes are very small, and so hidden amongst the fur that it is difficult to find them. External ears, which would not only be liable to injury, but would retard movement in the burrows, are absent. The hairs are so formed that they will lie either backwards or forwards according to the direction in which they may be rubbed, so that when the mole find it necessary to retreat backwards through the burrow, they do not offer any resistance. The nose is provided with a protective horny skin, supported by gristle. If the skeleton of the mole be compared with that of some more generalised mammal, such as the rat, it will be seen that the skeletal modifications for burrowing are equally striking. The bones of the shoulder and chest are fastened firmly together, and form a solid basis for the arm. The upper arm-bone (*humerus*) is broad, with large processes for attachment of the powerful muscles which move the arm in digging, and a median keel upon the breast-bone also serves to increase the area of attachment of the digging muscles. The burrows or " runs," as they are called, are usually placed in a sheltered spot, near a hillock or between the roots of two trees. There is always a central chamber or nest, lined with dried grass or leaves, which communicates with two circular galleries, placed one above the other. From the lower of these galleries, which is larger than the upper one, there are given off several diverging passages ; one of the latter, which is known as the " main run " and is larger than the others, leading to the burrows which are driven in various directions in order to secure food. The well-known mounds of loose earth sometimes called mole-hills, are merely the accumulations of earth pushed up out of the burrows from below. Moles burrow with great rapidity. A North American species of mole has been known to excavate a tunnel several yards long in a night.

The South African golden mole (*Chrysochloris trevelyana*) derives its name from the metallic sheen of its fur and the mole-like appearance of its body. It is, however, not strictly a mole, since its form has been acquired in adaptation to a burrowing life independently of the true moles. The eyes are hidden beneath the skin, as in the moles and in so many other subterranean animals. The feet have been modified in a different way to those of the moles, two of the front toes being furnished with enormous digging claws of great power. Both the mole and the golden mole belong to an order of mammals known as the Insectivora. It is interesting to note that in another order, the pouched mammals or Marsupialia,* adaptation to a subterranean life has produced a mole-like form, known as the pouched mole (*Notoryctes typhlops*). There are no external ears, and the eyes are buried in the skin, so that they have the appearance of black dots. On the fore feet the third and fourth toes are enormously enlarged and provided with great triangular claws, while the claws of the hind feet are smaller than those of the fore-, foot, but still large. The nose is provided with a quadrangular leathery shield, which protects it from injury while the animal is pushing its way through the soil.

In the order Rodentia there are several highly specialised burrowing animals. In the Cape mole-rat (*Bathyergus maritimus*) the familiar adaptations to subterranean life are found. The eyes are small, the external ears are absent, the claws are large, and the body is cylindrical. Other burrowing rodents are the great mole-rat (*Spalax typhlus*) and the mole-like vole (*Ellobius fuscicapillus*).

RUNNING.

[Cases 24 to 29, and table-case.]

It has been already pointed out that walking and running animals are here regarded as distinguished from creeping animals by the possession of paired, jointed limbs, such as are found in the lobster, lizard or dog. In practice, however, it is difficult to maintain these distinctions, as in many forms the locomotion might as be appropriately called walking as creeping, and also in many cases it is difficult to decide whether locomotion should be referred to as walking or running. Again, there is the difficulty that the locomotion

* Familiar examples of the Marsupialia are the kangaroo, wallaby, phalanger and opossum.

of very few running animals, and those only of the commonest types, has been investigated. In the following pages a few only of the most highly specialised running animals have been selected for description. It will be convenient to begin with the mammals.

MAMMALIA.—It will be observed upon looking at the specimens of running mammals that the limbs, especially the hind limbs, are bent upon themselves at a marked angle, the elbow being directed backwards, the knee forwards. The body is thus supported upon springs, which reduce the shock in running, and the above-mentioned angle at which the limbs are bent enables the animal to give powerful backward and downward thrusts, especially with the hind limbs, upon the ground, so that the body is projected forwards. The hind limbs are firmly secured to the bones of the pelvis, the two halves of which are not only joined together, but also securely united to the backbone, and this confers greater power upon the limbs in lifting the animal onwards. The adaptations for running may be studied in the horse, which is highly specialised for this mode of life.

If the skeleton of a fairly typical mammalian foot, say the hind foot, be examined (see the skeletons of the foot in the table-case) it will be found to consist of the following parts: (1) a series of small ankle (or *tarsal*) bones, arranged in two rows, one above the other; (2) five elongated *metatarsal* bones; (3) the toe-bones (or *phalanges*), of which there are two in the first digit, and three in each of the other digits; (4) five claws, one at the end of each toe.* Such a foot may be put to varied uses, such as scratching, walking, and running; but in the horse, whose foot is almost wholly a running organ, the parts are greatly modified. Length and slenderness of the whole leg and foot, together with strength and firmness is here necessary, and this result has been attained by reducing the number of the toes to one (the third), and lengthening and strengthening this one toe. The first and fifth toes have completely disappeared, and the second and fourth have become reduced, being represented merely by "splint bones." The claw of the third toe has become transformed into a large hoof, which encases and protects the terminal joint of the toe. The thigh bone and the upper bone of the fore-limb (*humerus*) are more or less completely embedded in the trunk and this close union confers greater power and strength upon the legs. On account of this conformation of the foot the heel is raised far above the ground, and has much the appearance

* The fore foot is essentially similar in structure, the bones corresponding to the tarsals being called *carpals*; those to the metatarsals, *metacarpals*.

of a backwardly turned knee, the true knee, of course, being against the flank; while the elbow is against the side of the chest, the wrist being what is commonly called the knee of the horse. The hoof serves not only to protect the toe by its thickness and strength but also, on account of its elasticity, to reduce the severity of the shocks to which the limb is exposed when the animal is running. Since the limbs of a horse are almost wholly devoted to locomotion, their action is practically restricted to a backward and forward movement, and the ankle bones (and also the wrist bones) are interlocked together so firmly that they form a compact mass whose units will not give so readily to strain and shock as to form a weak point in the column formed by the foot. It will be observed from the foregoing description that a horse actually walks upon four large nails, one on each foot. The backward thrusting action of the limbs above-mentioned is well seen in the statuette of the racehorse "Sysonby," which is shown in a galloping attitude. A foot of the type possessed by the horse is not fitted for walking over marshy ground. For such a habitat several toes, which spread outwards when the weight of the animal rests upon them, are necessary in order to sustain the animal.* Wild horses are usually found upon high grassy plains, and it is interesting to note that even domesticated horses are averse to trusting themselves upon soft or boggy ground. It is known that horses have arisen from small, five-toed and more generalised mammals, and have gradually become evolved into large animals suited to rapid progression over solid ground.†

The horse belongs to an order of mammals known as the Ungulata, or hoofed animals. Reduction in the number of toes, together with the acquisition of great running powers, has been independently effected in different groups of the Ungulata. Among the extinct South American sub-order known as the Litopterna are forms which in some respects were remarkably horse like, the third toe being enlarged, and the others reduced; in *Thoatherium* there was but one toe, as in modern horses. In the sub-order to which the deer, oxen, and antelopes belong (the Artiodactyla), represented in the collection by the roe deer (*Cervus capreolus*), reduction has taken place in all but the third and fourth toes, which are well developed and symmetrical to one another. It is probable that the two toes which have been retained in these animals are adapted to secure a firm footing on rough or

* The tapir and rhinoceros are examples.

† The evolution of the horse is treated in "The Evolution of Animals" section on the other side of the Hall.

precipitous ground. The single toe of a horse is not so well adapted for rapid locomotion on such ground.

Running forms are found amongst the order (Carnivora) which includes the dogs and cats. Dogs walk upon the toes, the heels being well above the ground, and the first hind toe is vestigial, while the first fore toe does not reach the ground. It will be seen that the dog is not so highly specialised for running as the horse. The herbivorous horse uses its legs almost wholly for running away when disturbed, but the carnivorous dog has to put its limbs to varied uses, and the separate, clawed toes have consequently been retained. A dog deliberately runs down its prey, but a cat secures it by stealth, hence cats are not good runners. They are able to progress rapidly by a series of bounds when occasion requires, but they resume their habitual mode of progression by walking as soon as possible. It is interesting, therefore, to note that in a species of cat known as the hunting leopard or cheetah (*Cynælurus jubatus*) which secures its prey by suddenly rushing upon it and running it down, the general proportions of the body are distinctly dog-like, and the limbs are longer than in any other cat. The hunting leopard is used by Indian potentates for sporting purposes, and is, for short distances, probably the swiftest of all mammals. It has been recorded that a tame hunting leopard caught a black-buck within four hundred yards, although the buck had two hundred yards start. A hunting leopard, it may be pointed out, does not attempt to follow its prey if it fails to secure it at the first rush, as it cannot get a "second wind."

BIRDS.—In the most highly specialised running birds modification has followed much the same lines as in the horse. In the ostrich, for example, there is but one very large toe (the third) and one smaller one (the fourth). An intermediate condition between that of the ostrich and ordinary four-toed birds is seen in the rhea (*Rhea americana*) in which there are three toes (the second, third, and fourth). In these birds and their allies the wings are small and useless for flight, and it would seem that in the course of evolution as the wings became smaller the legs became larger.

REPTILIA.—Many lizards are able to run, or scuttle, rapidly over the ground when alarmed. The frilled lizard (*Chlamydosaurus kingi*) has large hind legs, and when alarmed it raises its shorter fore limbs and its tail off the ground, and runs away very rapidly. It cannot, however, maintain this for any length of time. The frilled lizard presents an interesting analogy to certain of the extinct reptiles known as dinosaurs, which walked or ran upon their large hind legs.

JUMPING.

[Cases 30 to 32, and table-case.]

Jumping is such an efficient mode of rapidly retreating from, or of eluding by irregular leaps, the attacks of predatory animals, that as might be expected many animals of the most diverse groups have become modified for this mode of locomotion. In all cases the principle of the movement is the same; a vigorous thrust is given by some portion of the body upon the ground, and the animal is thus projected forward.

MOLLUSCA.—It has been already pointed out that the foot of a mollusc is used for very different modes of locomotion in different groups (see page 19). In the cockle (*Cardium edule*) it is used as a jumping organ. It will be seen upon examination of the cockle in the case that the long narrow foot is bent in an elbow-like manner, and when the animal is moving from one place to another the foot is extruded from the shell, pressed against the ground, and then strongly and vigorously straightened, so that the cockle is projected forward.

ARTHROPODA.—INSECTA.—There are veryvarious modes of jumping found amongst insects. In the common green grasshopper (*Locusta viridissima*) the hind legs, which are very long and strong, form the jumping organs, and the same is the case in the flea (*Pulex irritans*), and many other insects. The click beetle, or skip-jack (*Agriotes lineatus*) possesses an organ by means of which it is able to regain its feet if it falls upon its back during its irregular leaps (see diagrams in table-case). The common spring-tail (*Podura villosa*), a tiny insect often found congregated in numbers under flower-pots, stones or dead leaves, has a forked tail, which is usually turned forwards beneath the abdomen, but when released it springs backwards and strikes the surface of the ground with such force as to throw the insect into the air. The water springtails (*Podura aquatica*) float on the surfaces of pools, and, by striking their tails against the surface film of the water, jump into the air.

VERTEBRATA.—AMPHIBIA.—The common frog (*Rana temporaria*) is a well-known jumping animal. Jumping is effected by the long and strong hind legs. It may be pointed out that each of our three British tailless amphibians has its characteristic mode of locomotion; frogs jump, natterjacks run, toads walk.

MAMMALIA.—It has been already pointed out in speaking of running mammals that the hind limbs are not only larger and stronger than the fore-limbs, but are bent upon themselves at a marked angle. The reason of this is, of course, that the hind limbs exert a vigorous backward and downward thrust upon the ground so that the animal is projected forwards. In those mammals which we have now to consider the hind limbs are very much larger than the fore limbs, so that the forward projection of the body, when the hind limbs are brought into use, is much more marked, and the animal progresses by means of a series of leaps. In the common squirrel (*Sciurus vulgaris*) which jumps easily and quickly about the boughs of trees the hind limbs will be seen to be markedly larger than the front ones, and this is even more the case in the lemurs, represented here by the gentle lemur (*Hapalemur griseus*), which are able to take long leaps from tree to tree. Both these forms use all four limbs in locomotion, but in the most highly specialised jumpers the hind limbs alone are used in rapid locomotion, and the animals only occasionally place their fore feet upon the ground, as when at rest. The kangaroo is probably the most familiar of these jumping forms. In the hind leg, length of limb, consistent with strength and firmness, is as necessary as in the horse (page 27), and we find, accordingly, that the thigh is short and intimately united to the trunk, while the lower leg is long; one toe, the fourth, is large, the fifth is smaller, the second and third are nothing but slender rods bound together in a common skin, the first is absent altogether; and the whole foot is elongated. In the jerboa (*Dipus deserti*) there are but three toes on the hind limb, and the three metatarsal bones are fused together to form one long, slender bone. The speed of the jerboa is very great, and when pursued the animal is able to take leaps of as much as nine feet in length in such rapid succession that it appears to fly over the ground. When walking the jerboa moves its legs alternately in the ordinary manner, but when jumping the two limbs are moved simultaneously; the kangaroo moves its two limbs simultaneously at all times, and may, therefore, be regarded as more highly specialised. The jumping shrew (*Macroscelides rozeti*), or elephant shrew as it is sometimes called in allusion to its long snout, is not so specialised as the kangaroo and jerboa, as the foot, although it is elongated and forms a compact mass, has the usual five toes, and the metatarsals separate.* Each of these three examples represents

* In an East African species (*M. tetradactylus*) the first toe is absent, and this animal (not represented in the collection) is therefore more highly specialised.

a distinct order of mammals, the kangaroo belonging to the Marsupialia, the jerboa to the Rodentia, the jumping shrew to the Insectivora. The convergence between them is so marked that anyone unacquainted with their anatomy would at once declare them to be allied forms. It will be observed that the tail in jumping animals is long and heavy (kangaroo and jerboa) or in those forms which spring from tree to tree is long and bushy (squirrel and lemur). The heavy tail acts as a counterpoise to the rest of the body in jumping, and probably as a steering organ also in those forms which jump from tree to tree.

CLIMBING.

[Cases 33 to 35, and table-case.]

Climbing not only enables an animal to retreat from foes upon the ground, but may also, as in the case of an arboreal form, bring within its reach the store of food, such as leaves and fruit, borne by the trees. Again, a climbing animal can make its home in rocks or on the trees, and so bring up its young with a greater measure of security than on the ground. Certain of the arboreal forms are of especial interest, as it seems probable that from animals which jumped from tree to tree or from trees to the ground, the terrestrial parachuting animals took their origin, as will be described later. The number of climbing animals is so large that only the more instructive examples can be described.

VERTEBRATA.—AMPHIBIA.—An interesting adaptation for climbing is seen in the familiar European green tree-frog (*Hyla arborea*), which is so often kept as a pet in greenhouses. The under surface of the terminal joint of each toe is expanded into a flattish adhesive disc, which can be adjusted to the surface of a leaf or bough. With the aid of these discs, whose adhesive power is increased by the slimy secretion poured out from glands upon their surfaces, a tree-frog is able to walk up a vertical pane of glass.

REPTILIA.—The majority of the lizards known as geckos possess structures recalling those of the tree-frogs. In the gecko (*Gecko verticillatus*) exhibited, it will be seen that the joints of each toe are expanded, and bear on their under surface a number of transverse folds.* Pressure

* These folds can be clearly seen in the feet of a gecko preserved in spirit in the table-case. The arrangement of the folds varies in different species of gecko.

of the foot upon a smooth surface drives the air from between the folds, and partial retraction of the foot produces vacua, so that the foot adheres to the surface. By this means a gecko is able not only to ascend a vertical pane of glass, but also to run with facility upside-down upon a smooth ceiling. The efficiency of the pads is increased by the hair-like bristles, with which they are provided. It is interesting to note that in certain kinds of gecko, such as *Teratosaurus scincus*, which have become modified for life on desert sands the pads have disappeared or become modified.

In the chamæleon (*Chamæleon vulgaris*) the digits on each foot are divided into two opposable groups, so that the foot forms a most efficient grasping organ. In the fore-foot one group is composed of the first, second and third digits, and the other group of the fourth and fifth ; in the hind foot the two groups are composed respectively of the first and second, and third, fourth and fifth. The long tail is prehensile, and is used for holding on to the branches and twigs of trees.

BIRDS.—In an ordinary perching bird, such as the pigeon, the first toe is turned backwards, while the second, third and fourth toes are turned forwards, the fifth being absent. The toes thus form two opposable groups, well fitted for grasping a branch of a tree when the bird is perched upon it. But in certain birds, the common green woodpecker (*Gecinus viridis*), for example, which creeps up vertical tree trunks in searching for its food (insects and their larvæ) the fourth toe is also turned backwards to assist in supporting the weight of the body.† This *zygodactyle* foot, as it is called, is found also in the parrots, in which group it forms such a perfect climbing and grasping organ that a parrot is able to hang upside down by one foot and carry food to its mouth with the other, as may be seen in captive examples. In the colies the first and fourth toes can be turned backwards or forwards at will. In the trogons, the two forwardly directed toes are the third and fourth and the hinder ones the first and second. In the woodpeckers the short stiff tail-feathers are used to assist the bird in climbing, and in the parrots the beak is much used for the same purpose. The tenacity with which the claws of woodpeckers grasp the bark of the tree trunk is illustrated by the fact that when killed by being shot, they have been known to remain suspended from the tree by their feet.

† It is probable that the fourth toe became turned back in order rather to replace the feebler first toe than to assist it, as in certain woodpeckers which appear to be fully as expert in climbing as their relatives, the first toe has disappeared, and the work of supporting is done by the fourth toe alone.

MAMMALIA.—There are many kinds of climbing mammals, and all degrees of specialisation may be traced in the class.

Among the order Marsupialia the opossum (*Didelphis marsupialis*) and the cuscus (*Cuscus maculatus*) are climbing species in which the terminal portion of the prehensile tail is devoid of hair to enable the animal to take firm hold of branches. In the koala (*Phascolarctus cinereus*) the tail is very short, but the fore-foot forms a grasping organ recalling that of the chamæleon, the two innermost toes (*i.e.*, the first and second) being completely opposable to the remaining three.

Of the order Edentata three examples are shown: the pangolin, two-toed sloth and the two-toed ant-eater. The mail-clad pangolin climbs by means of its long, sharp claws, but the backwardly projecting scales of the side of the body, and especially of the side of the tail, act as scaling irons in climbing. The two-toed sloth (*Cholœpus didactylus*) is not only the best known but is the most highly specialised of all arboreal mammals. The sloth moves and sleeps upside down. The specimen in the case is shown in a walking attitude. The arms are very long, as it is important that an arboreal animal should have as long a reach as possible, and as the radius (or smaller of the two bones of the forearm) is capable of considerable rotation over the other bone, or ulna, the whole forearm and hand have a wide range of movement, another important adaptation in an arboreal animal. The first, fourth and fifth toes have disappeared, the second and third bear enormous long curved claws, and the digits and foot are together enveloped in one fold of skin. The whole fore-foot is thus reduced to the condition of a hook which suspends the sloth from the branch of a tree. There are three toes upon the hind foot, each bearing a large hook-like claw, and the whole foot is articulated obliquely to the leg in such a manner that if placed upon the ground the sloth would be able to walk only on the outer edge of the foot. Examination of the specimen will readily demonstrate the utility of this arrangement of the foot in climbing.

The ant-eaters are very unlike the sloths in appearance and mode of life, but the two-toed ant-eater (*Cyclotourus didactylus*) has become so adapted for an exclusively arboreal life that it externally resembles a small sloth, although the tail at once distinguishes it therefrom. The fore-foot has four toes, the second and third alone bearing claws, of which the third is of great size and hook-like in shape. The toes of the hind foot are nearly equal sized, and are placed close together so as to form a hook-like organ. The long tail is prehensile.

Among the monkeys the spider monkey (*Ateles ater*) is shown as being a specialised form. The arms are elongated, the first digit of the hand is absent, and the whole hand is narrow and elongated and is used in a hook-like manner, as will be observed in the specimen. The under surface of the tip of the long prehensile tail is devoid of hair, as we have seen to be the case in certain other long-tailed climbing mammals.

PARACHUTING.

[Cases 36 and 37.]

In all parachuting animals an expansion of some portion of the body presents a large surface of resistance to the air and supports the animal for a longer or shorter period after it has launched itself into the air. The part of the body from which this expansion is formed varies, as will be explained in the following paragraphs. Most parachuting animals are also arboreal animals. This is an especially interesting point, as it seems probable that from animals which jumped from tree to tree, as does the squirrel of the present day, the parachuting animals of the land took their origin. It is not difficult to imagine that in an animal which took these long leaps a slight lateral expansion of the side of the body arose and proved of such advantage as a parachute that it was retained and increased during evolution. Parachuting in its turn leads on to flying.

VERTEBRATA.—FISHES.—In the flying fish (*Exocœtus evolans*) the broad, elongated pectoral fins form the supporting organs when the fish is taking its aerial flights. There is considerable difference of opinion as to the method by which the fish is sustained in the air, and the matter cannot yet be regarded as definitely settled. All observers appear to be agreed that the flights are primarily taken by the fish in order to escape the pursuit of enemies in the water; but while some think that the pectoral fins may be used as organs of true flight, though of a feebler kind than that of birds, others think that the impulse which shoots them through the air is delivered solely by the tail before leaving the water, and that the movements of the fins which have been often remarked are nothing but the vibrations caused by the resistance of the air. Two or three hundred yards would appear to be a fair flight for these fish, although it has been stated that this distance may be doubled upon occasion. They rarely rise more than a few feet above the water, although they overtop succeeding waves by being carried up by the pressure of the disturbed air, and in breezy weather may be even carried on to the deck of a ship by the same cause. The fish does not appear to have any power of voluntarily changing its course in the air, although this may be altered by the tail incidentally dipping into a wave, or by diversion of the air currents. It will be observed in looking at the specimen of the flying fish that the lower lobe of the tail-fin is markedly larger than the upper lobe. Vigorous use of such a fin will give the fish an upward bias in the water, and, in the absence of correction by the pectorals, will project it into the air. The flight is rapid, ten miles an hour or more it has been said, but the speed gradually decreases until the fish falls back into the water.

The flying gurnards, represented in the collections by *Dactylopterus volitans*, have acquired their power of "flight" quite independently of the flying fish. They do not appear either to frequent the surface waters or to leave the water on such frequent or long extended flights as the true flying-fish.

REPTILIA.—In the pretty little Malayan parachuting lizard, miscalled the "flying dragon" (*Draco volans*), there is a membranous expansion of the side of the body, which is supported by six ribs on each side. The parachute, whose somewhat concave under-surface increases its supporting power, can be closely folded up against the body when not in use. The lizard is essentially arboreal in its habits, and when springing from tree to tree or from branch to branch it moves very rapidly. When the parachute is extended its brilliant colouring is said to resemble some gorgeous tropical flower. The fringed gecko (*Ptychozoon homalocephalum*) has an expansion of the skin of the sides of the body and tail, and the toes are webbed. This lizard is said to use its parachute as an aid in jumping from branch to branch, as does the flying dragon.*

MAMMALIA.—Amongst the mammals parachuting forms are found in the orders Rodentia, Insectivora, and Marsupialia. In all cases more or less of the skin of the side of the body is expanded to form the parachute. In looking at these parachuting mammals it is difficult to believe that they are not all related species; indeed, examination of their structure

* This expansion causes the outline of the lizard's body to merge into the bark when the animal is clinging to a tree. It would thus appear to serve the double purpose of concealment and parachuting.

is necessary before the essential differences between them can be appreciated. The flying rodents may be divided into two groups, the flying squirrels of Europe, Asia, and North America, and the scale-tailed flying squirrels of Africa, and each of these two groups has independently acquired the parachuting mode of life. The former group is represented in the collection by *Pteromys nitidus* and *Sciuropterus volucella*, the latter group by *Anomalurus beecrofti*. The anomalures may be at once distinguished by the presence of a series of overlapping horny scales upon the under surface of the base of the tail, whence their name of scale-tailed flying squirrels. These scales help the animal in climbing up the stems of trees, in much the same way as the short stiff tail-feathers assist the woodpecker. There is also a cartilaginous rod projecting from the elbow to the edge of the membrane, and this serves to support the membrane. In the flying squirrels of the Northern Hemisphere the scales are absent and the cartilaginous rod extends from the outer side of the wrist along the anterior border of the parachute.

In the cobego (*Galeopithecus volans*), which belongs to the Insectivora, the fold is extended to include the whole of the tail. In the other parachuting mammals the tail is more or less bushy, and probably acts as a steering organ during the flying leaps. That these parachuting species have the power of guiding themselves to some extent is amply proved by the researches of different observers. Mr. A. R. Wallace, speaking of the cobego in Sumatra, says: " Once, in a bright twilight, I saw one of these animals run up a trunk in a rather open place, and then glide obliquely through the air to another tree on which it alighted near its base, and immediately began to ascend. I paced the distance from one tree to the other, and found it to be seventy yards, and the amount of descent I estimated at not more than thirty-five or forty feet, or less than one in five. This, I think, proves that the animal must have some power of guiding itself through the air, otherwise in so long a distance it would have little chance of alighting upon the trunk." That they must have means of steering is also shown by their method of alighting. Audubon and Bachman describe an American flying squirrel (*Sciuropterus volucella*) as " . . . darting from the topmost branches of a tall oak, and with wide extended membranes and outspread tail, gliding diagonally through the air, till it reached the foot of a tree about fifty yards off, when at the moment we expected to see it strike the earth it suddenly turned upwards and alighted on the body of the tree." Gould has also described this terminal ascent in a parachuting marsupial (*Petauris australis*) as preventing the shock the animal would otherwise sustain.

It will be observed that the name "flying" popularly applied to so many of the parachuting animals is a misnomer, as, of course, they do not really fly.

FLYING.

[Cases 38 to 44, and table-case.]

We have already seen that in the various groups of the parachuting animals a stage in the evolution of flight has been reached, *i.e.*, support by an expansion of the body during long leaps. In the animals we have now to consider the adaptations for sustained flight are of the greatest specialisation, and the animals are able not only to move rapidly in the air but to support themselves for long periods of time and there perform the most varied evolutions. Flight has been acquired independently in four distinct groups of animals, *viz.*, in the insects, pterodactyls, birds and bats.* It will be convenient to begin with the **BIRDS**, as it is in that group that the method of flight has been the most fully investigated.

Structure of birds in relation to flight.—The general shape of a bird is such as to fit it for rapid locomotion. The pointed head, followed by the smooth rounded body, is adapted to cleave easily through the air. The bird's organs are so arranged that the centre of gravity is on the lower portion of the body, as nearly as possible below the point of suspension by the wings, and the body is so delicately poised that outstretching of the neck or raising or lowering of the tail enables the bird at once to rise or sink in the air.

The bones of the wing are homologous with the bones of the front limb of any other higher vertebrate, such as a lizard, dog or man; in other words, a wing is nothing more than a highly modified front leg, the feathers with which it is clothed being in their turn the modified scales of the primitive reptilian ancestor of the bird. Firmness of the wing-bones being necessary, two of the original five digits have disappeared, and of the remaining three, two (the second and third) are more or less completely fused together, and the other (the first) is small. Flaps of skin extend between these fingers,

* The number would, of course, be raised to six if the flying fishes *Exocœtus* and *Dactylopterus* be regarded as truly flying animals.

between the neck and shoulder, and between the elbow and side of the body, such flaps being suggestive of the parachuting folds, but in the bird the extent of the wing is increased by the long elastic quill-feathers with which it is furnished. While the expanse of the wing is elastic, it is rendered strong by the rod formed of the arm and finger bones. The muscles which move the wings are of relatively enormous size and are concentrated on the breast in accordance with the above-mentioned necessity for location of the centre of gravity on the lower part of the body. In order to afford a sufficient area of attachment for the origins of these great muscles, the breast bone of a bird is large and carries a deep keel along its centre. Of these muscles the one which is concerned in producing the downward stroke of the wing (that is, the stroke which requires the greatest power, as will be explained later) is the *pectoralis major* (see dissection of the breast muscles). Beneath it lies a smaller muscle, the *pectoralis minor*, which raises the wing after the downstroke, and it will be observed that its tendon runs upwards, curves round the bones of the shoulder to reach the upper surface of the arm-bone (*humerus*), so that contraction of the muscle raises the wing although the muscle lies below it. The joints of the back-bone in the trunk region are largely fused together to form a firm central support for the body, and the terminal joints of the short tail are fused into a "ploughshare bone" from which the steering tail-feathers radiate in a fan-like manner.

The flight of birds.—The method by which flight is accomplished is not only difficult to investigate, but is even yet not thoroughly understood, and it will, therefore, only be possible to explain here the more salient points. Those who may be desirous of pursuing the matter further are referred to the list of books in the Museum library given on page 47.

In all the animals we have so far considered (with the exception of the parachuting forms) the animal was supported by the ground or by the water, and the main problem to be considered was the mode in which locomotion was effected. But in the case of flying animals we have to consider how the animal is supported as well as how it moves.

It is important, first of all, to understand clearly that the possibility of flight is due to the resistance which the air offers to any body moving rapidly through it. This resistance is experienced every day by cyclists and motorists. The quicker the movement of the body, the greater the resistance offered by the air. A kite may be used to illustrate the mode in which a bird utilises this resistance in order to obtain support in the air. If the wind be blowing at right angles to the flat surface of a kite, the latter will, of course, be blown backwards. But if the kite be pulled forwards, by a string held by a boy, against the wind, the kite moves obliquely upwards, in the direction of least resistance; in other words, the resistance offered by the air to the pull upon the kite supports the kite. The result is the same whether the boy stands still while a strong wind blows against the kite, or whether there is no wind and the boy replaces it by running along with the string. The air will support the kite provided the kite moves quickly enough. A bird with extended wings may be compared to a kite, but the bird differs from the kite in that its motive power lies within itself and it can not only support itself by rapid motion, but can perform a thousand delicate movements which enable it to take advantage of every current and eddy of air. And just as the kite can be made to mount upwards in still air by the boy running with the string so the bird is supported in the absence of a wind because the rapid rate at which it moves supplies the place of the wind. It is interesting to note that many birds deliberately make their initial jump into the air in the face of the wind in order to get its support, and this is particularly the case in those birds which perform the difficult feat of taking flight from the surface of the water. So important is this leaping start in order to give the bird its initial momentum, that the swift, on account of its feeble legs, only rises from the ground with difficulty, in spite of its efficient wings. Indeed, all heavy birds with short or weak legs have this difficulty. It must not be imagined that the foregoing comparison with a kite implies that the bird is an unusually light structure. A bird can in no sense be compared to a balloon. Weight is indeed a necessity for flight, since without it a bird would not only be unable to bring its wings into action to tread the air, but would be swept along at the mercy of every gust of wind.

The movements of the wings may be studied with the aid of the series of pigeons in the cases. The wing movements are essentially up-and-down movements. In specimen 1 the wings are raised ready for the down-stroke.* The down-stroke is directed downwards and forwards, and during the stroke the whole wing becomes arched and the front edge descends more rapidly than the hinder, so that the wing takes the shape and position shown in specimen 3, the under side of the wing facing downwards and backwards. The bird is lifted upwards and onwards owing to the resistance offered

* In vigorous use of the wings the upper surfaces strike against one another across the back and produce the clapping noise which is heard when a pigeon rises hastily.

by the air to the very rapid downward and backward stroke of the wing. A bird is, however, able to do more than raise itself upward and onward; by adjusting its wings and body to the right angles, it is able to maintain a level in flight or lift itself upwards, and its tail is used in steering and balancing. The up-stroke is due not only to muscular action, but to the recoil of the wing from the resistance offered to the down-stroke, as well as from the downward fall of the heavy body after its upward lift in the course of the down-stroke. It is the down-stroke which pulls the bird onwards, and it has been previously pointed out that the muscle which effects it is very large. The position of the wing during a portion of the up-stroke is shown in specimen 4, and it will be observed that the wing takes somewhat the shape of a cone with the apex upwards, a shape which allows of easy motion of the wing through the air. Again, during the down-stroke the quill-feathers of the wing are placed close together, so as to present an unbroken surface to the air, but during the up-stroke they are rotated in such a way as to separate a little and permit of the air flowing between them. It will be noted from the foregoing description that during the effective down-stroke the wing is arranged so as to seize the air; during the up-stroke to evade it. Specimen 6 shows the pigeon alighting. The body is depressed posteriorly so as to decrease the onward speed, and the wings and tail are spread out so as to prevent a too sudden descent upon the ground.

Gliding flight is a mode of progression performed by a bird when it ceases to beat its wings and glides through the air with the wings outspread, merely balancing itself by adjusting the angles of its wings or body. Sea-gulls may be often watched taking advantage of every current of the air displaced by a moving ship to glide rapidly along, occasionally performing varied evolutions by a few bends or turns of wings or body.

Soaring is the name given to the ascent of a bird high into the air in a spiral manner, the bird first raising itself by wing beats to a certain height, and then appearing to glide upward in wide curves with motionless outstretched wings. Some birds soar to great heights, the adjutants to as much as two miles from the ground. The method by which soaring is performed is not understood, but birds are apparently unable to soar in the absence of a certain amount of wind, and soaring seems to be possible only in those birds which possess a large extent of wing compared with weight of body.

MAMMALIA.—Comparison of the fore limb of the bat and bird shows that in each case the limb has been modified for flight, but the result has been attained in different ways. In the bat four of the fingers are greatly elongated and assist in bearing a wing-membrane, which extends outwards from the side of the body and hind legs to be attached to the fingers. There may also be a membrane extending between the tail and the hind limbs. When not in use the wings of a bat can be folded up in a fan-like manner.

There is little or no motion possible between the individual joints of the backbone in the trunk region, most of them being fused together. A firm axial support for the body is, of course, as necessary in bats as in birds. The breast-bone is keeled, as in birds, to afford a larger area of attachment to the muscles of flight. The feeble hind limbs are only occasionally used when the animal is crawling on all fours, and they are twisted outwards and backwards to assist in supporting the membrane. Bats are not only expert flyers, being able to turn quickly and skilfully in the air, but are able to fly for considerable distances.

REPTILIA.—The true flying reptiles, or pterodactyles, are all extinct. In the pterodactyle, one finger (the fifth) is greatly elongated, the others being small, and it supported the outer border of the membrane which was present in life. In some pterodactyles in which a tail was present, the membrane also extended between the tail and the hind limbs. In *Rhamphorhynchus* the end of the tail was expanded in a paddle-like manner, and it is probable that this tail was used as a steering organ during flight. Some of the pterodactyles were not larger than a sparrow, but in *Pteranodon*, of which a restoration is shown, the extended wings could span twenty feet or more.

ARTHROPODA.

INSECTA.—In all the flying animals so far described the fore limb has been modified into an organ of flight, but in the insects the wings are developed as fold-like outgrowths of the integument and thus differ fundamentally from the wings of other animals. Insects are the most abundant and successful of all invertebrate animals, and this is doubtless due to their power of flight. In them this power is found in perfection, as may indeed be realised if it be recollected that a house-fly, in spite of its small size, can move as fast as a racehorse and take to wing or settle on the ground with the greatest ease and precision, while its wings may move at the rate of 330 beats per second. Certain insects, the common water-beetle (*Dytiscus marginalis*) for example, are specialised for swimming (page 9) as well as for flying.

The wings, which are borne upon the thorax, are horny, elastic membranes, strengthened by *nervures*. An especially strong nervure runs along the front border of the wing and serves to give rigidity to this region so that it is able easily to cleave through the air.

The wings in insects are typically four in number, but in many groups there is a tendency towards reduction of one pair, or to attach the hind pair to the front pairs so that the former lose much of their independence. In the flies the hind wings are reduced to club-shaped "balancers" (*halteres*). In the beetles the front wings form horny covers (*elytra*) for the hind wings. In yet other forms, the flea, for example, the wings are almost absent, being represented merely by scale-like vestiges.

The investigation of the mode of flight in insects is attended with great difficulty. It is known, however, that the wing movements are essentially up-and-down movements, and that the plane of the wing is inclined during these movements so as to drive the insect upwards and forwards, as in birds.

SECONDARILY FLIGHTLESS ANIMALS.—Flight was probably a power originally acquired for the purpose of escaping enemies. In certain oceanic islands, or places where there is little liability to attack from predatory animals, birds occur which have lost the power of flight. Such were the (now extinct) dodo of Mauritius and the solitaire of Rodriguez. The apteryx and the owl-parrot of New Zealand are flightless birds which are approaching extinction. In the flea, which may be regarded as an aberrant fly, the wings, which would be a source of embarrassment when the flea was moving about in the fur of its host, have practically disappeared. In Madeira and in many other islands there are numerous beetles which have small or vestigial wings and are unable to fly. It would appear that these beetles are in danger of being blown out to sea and lost, and in the course of evolution the wings have become reduced.

SOME OF THE BOOKS AND PAPERS IN THE HORNIMAN LIBRARY WHICH DEAL WITH THE SUBJECT OF ANIMAL LOCOMOTION.

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