NATURE SERIES

T. GEORGE MIVART, F. R. S.

THE COMMON FROG

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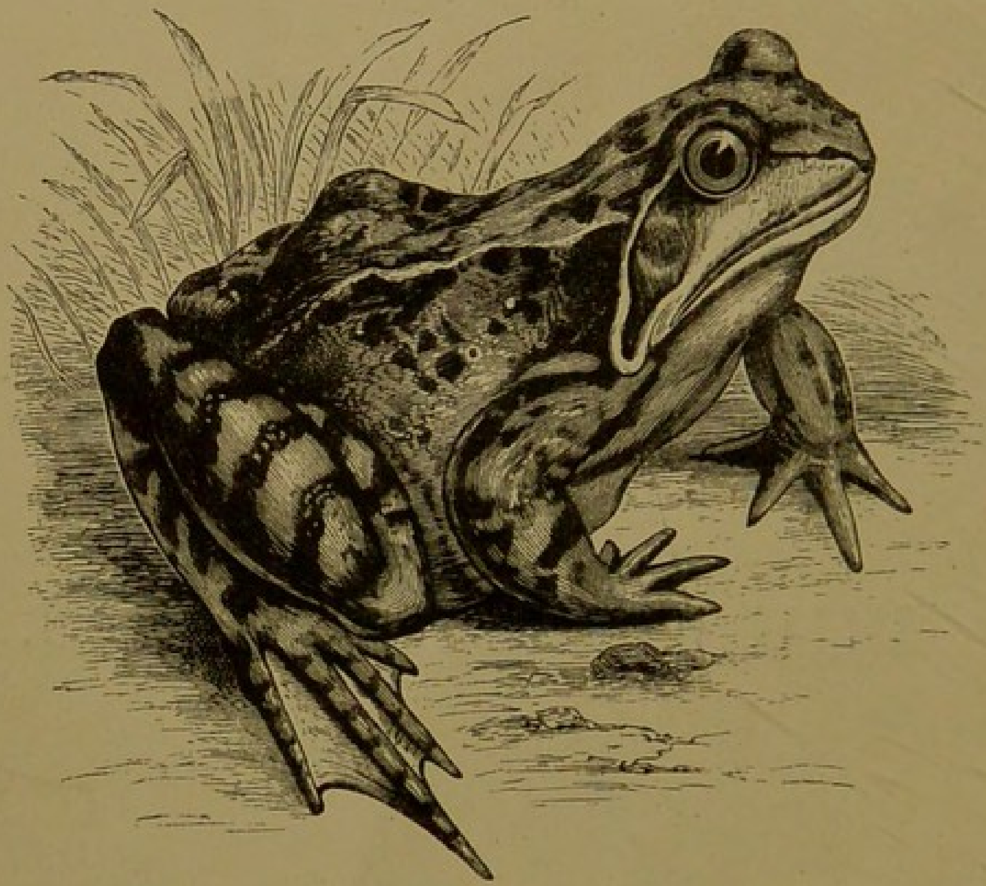

THE COMMON FROG.

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BY

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THE COMMON FROG.

CHAPTER I.

WHAT is a Frog? At first, almost all persons will think, on meeting with this question, that they can answer it readily and easily. Second thoughts, however, will show to most that such is by no means the case.

Indeed many a man of education and culture will find himself entirely at a loss, if suddenly called upon for a reply to what is in fact a problem by no means easy of solution.

"The Frog is a small saltatory Reptile" will probably be the reply of the majority. But *is* it a Reptile? At any rate it begins life (in its Tadpole stage) like *a Fish.*

By the great Cuvier, however, as by very many naturalists since, it has been regarded as a Reptile, and classed with Lizards, Crocodiles, and Serpents; and yet it may be a question whether the murine affinity connubially assigned to it in the Nursery tale, be not the lesser error of the two.

If the Frog was only known by certain fossil remains, it would be considered one of the most anomalous of animals.

Many persons are accustomed to make much of the distinctive peculiarities of the human frame. In fact, however, Man's bodily structure is far less exceptional in the animal series, is far less peculiar and isolated than that which is common to Frogs and Toads.

The number and nature of both the closer and the more remote allies of the Frog; its distribution both as to space and as to time; its relationships whether of analogy or affinity[1] to very different animals; its bony framework; its muscles and nerves; its brain and sense organs; its respiratory and excretory structures; its various changes from the egg to maturity, together with peculiarities of habit in allied forms,—are all matters which will well repay a little attentive consideration.

Indeed it is probable that no other existing animal is more replete with scientific interest of the highest kind, than is the Frog.

About it are gathered biological[2] questions which bear upon the origin of species, and upon the course and mode of organic development, as well as other speculative problems to which answers are as yet far to seek.

[1] Analogous relationship refers to the uses to which parts are put. Relationship of affinity refers either to such a relationship as that of kindred or to an ideal affinity reposing on similarities of structure.

[2] Biological questions are questions referring to living beings, "Biology" being the science which treats of all living things, including both plants and animals.

If it is a fact that all the various species of animals have arisen through ordinary generation one fron. another by a process of development, the life history of the Frog may with reason be expected to have some bearing upon such a process, since every Frog begins its free existence with the organization of a Fish, and after undergoing a remarkable "Metamorphosis," attains the condition of an air-breathing quadruped, capable of easy and rapid terrestrial locomotion.

There is a matter with respect to which the zoologist can hardly avoid regarding the botanist with envy. The creatures sought after by the latter may be rare or inhabitants of stations difficult of access, but at any rate they are incapable of flight or concealment, and specimens of some kind or other generally present themselves in plenty.

On the other hand not only does the townsman of a thickly-peopled land like our own, often meet with fewer animals in his country walks than he anticipated, but the explorer of tropical lands and virgin forests has frequently to endure disappointment from the contrast between the richness of a known local fauna and the little to be actually seen of the animal population of the place.

Frogs and Toads, however, are often enough seen both at home and abroad, and when perceived generally fall a far more ready prey to the collector than do the swift-running Lizards and small Beasts which are the commonest ground-animals met with besides. The group is also rich in species as well as in individuals, and it is spread over the far greater part of the habitable globe. Nevertheless Frogs and Toads have few admirers even amongst professed zoologists, and meet with no little neglect.

While the term "Ornithologist"[1] is familiar to everyone, and the title "Erpetologist"[2] is so to all naturalists; the name "Batrachologist"[3] has not yet been conferred on or assumed by any one worker in Science.

Economically, Frogs are of little esteem in England, save occasionally for bait and as the staple food of certain rare and interesting animals preserved in our menageries. Our American cousins indeed have given one more evidence of their French sympathies by the introduction of the Frog into their *cuisine*, and, as suits that land of the longest rivers and the largest lakes, it is no less a creature than the gigantic Bull-frog which figures in the *menu* of Transatlantic *gourmets*.

If zoologists and economists have neglected the Frog, the same assertion can by no means be made with respect to physiologists.

The Frog is the never-failing resource for the physiological experimenter. It would take long indeed to tell the sufferings of much-enduring Frogs in the cause of Science! What Frogs can do without their heads? What their legs can do without their bodies? What their arms can do without either head or trunk? What is the effect of the removal of their brains? How they can manage without their eyes and without

[1] Ὄρνιθος, a bird, and λόγος, a discourse.
[2] Ἑρπετόν, a reptile, and λόγος.
[3] Βάτραχος, a frog, and λόγος.

their ears? What effects result from all kinds of local irritations, from chokings, from poisonings, from mutilations the most varied? These are the questions again and again addressed to the little animal which, perhaps more than any other, deserves the title of "the Martyr of Science."

To return to our question at starting, "What is a Frog?"

To answer this, it will in the first place be well to make a certain preliminary acquaintance with the Frog absolutely.

Secondly, to study those creatures which are most like it, and are, therefore, as we shall directly see, its "class fellows," living and fossil.

Thirdly, to investigate its anatomy so far as to be able to institute fruitful comparisons, between its organisation and that of all other creatures belonging to the same great primary group of animals to which it pertains.

Fourthly, to sum up the results in a series of successively wider and wider comparisons, and by the light thence derived to answer as fully as the present state of Science allows the question first asked.

We shall then be able to answer that question, because we shall have ascertained how various parts of this creature form one organic whole as a system of mutually related structures; and how this whole and its parts are related to the entire series of animal existences from the monad up to man. Then, and then only, shall we be able to say what a Frog is.

In the first place it is necessary to acquire a general notion of the way in which animals are distinguished and segregated into groups, as well as the general system of arrangement of those groups, and the mode of bestowing names which has been adopted by zoologists in common with botanists.

When we have acquired an adequate general notion of zoological classification we shall be able to see with what creatures the Frog is now admitted to be, in various degrees, allied.

The whole mass of animals of all kinds, from man down to the lowest animalcula, is spoken of by the fanciful term *kingdom*. Thus we have the animal kingdom, in contrast with and in distinction from the vegetable and mineral kingdoms.

This great whole, the animal kingdom, is subdivided into seven great groups or *sub-kingdoms*, to one or other of which every animal known to us belongs.

Each of these sub-kingdoms (like every more subordinate zoological group) is characterised and defined by certain points of structure possessed by the animals which compose it, and which serve to distinguish them.

Thus, if we take up an earthworm we see that its body is composed of a series of similar segments or rings placed one behind the other, and we know that it belongs to that great sub-kingdom of ringed animals termed *Annulosa*.

If we examine a thousand-legs or a wood-louse we see that here again the body is evidently composed of a series of rings or segments, to most of which jointed legs are attached. A successive survey of a lobster, a scorpion, a bee, a beetle, or a butterfly will reveal to us that all these creatures, however different in other respects, all belong to the same ringed type, *i.e.*, that they are all members of the same sub-kingdom *Annulosa*, which contains all such animals, all insects, together with spiders, earthworms, and leeches.

Another great sub-kingdom called *Mollusca* contains all snails, slugs, cuttle-fishes, and creatures of the oyster and scallop class. Such animals have not the body composed of a series of similar segments, but are united by characters less obvious indeed, but as distinctive.

A third sub-kingdom called *Molluscoida* is made up of the sea-squirts, or Ascidians (sometimes called Tunicates), and lamp-shells, together with minute animals living in water in compound aggregations, like the *Flustra* (or Sea-mat) so common on our coasts, the surface of which is pitted with small depressions, in each of which a minute animal had in life its abode—as doves in a dove-cot, if we imagine each dove fastened in its cell by natural growth.

A fourth sub-kingdom, *Annuloida*, is composed of such animals as star-fishes and sea-urchins, together with internal parasites (tape-worms, &c.) and their allies.

The fifth sub-kingdom is named *Cœlenterata*, and contains all sea-anemones, jelly-fishes, Portuguese men-of-war, polyps, and coral animals—these last being the little creatures which have formed the atolls (or coral islands) of southern seas, and the vast reefs which stretched for so many hundred miles on the earth's surface.

The sixth sub-kingdom, *Protozoa*, comprises the

Sponges, the Infusoria, and all the lower forms of animal life.

Now the whole of these sub-kingdoms may be contrasted with the last and seventh, which bears the name *Vertebrata*, from which they all differ in several important particulars, and therefore they are often spoken of by the common and convenient term *Invertebrata*.

When we examine a fish (such as a sole, a herring, or a mackerel), one of the first things likely to be noticed by us on dividing it, is a solid structure—the backbone—extending from the head to the tail, and coated externally by the flesh.

This backbone is soon seen to be made up of a number of pieces jointed together. Each piece is called in natural history a *vertebra*, and every animal in which such a structure is found, is called, on that account, a Vertebrate animal.

Now every kind of beast and reptile agrees with these fishes in the possession of the vertebrate backbone, as well as in a variety of other important characters, which constitute the definition of the sub-kingdom *Vertebrata*.

Thus in the development of the egg of every Vertebrate (such *e.g.* as in that of the fowl), the first indication of the future animal, is the appearance on part of its surface of a minute longitudinal furrow called the *primitive groove*. Next the margins of this groove ascend to meet together above, thus enclosing a canal, the lining of which becomes thickened and transformed into no less important a structure than the brain and spinal marrow.

Concomitantly with the development of this canal, there is found, immediately beneath it, a little gelatinous rod enclosed in a membraneous envelope, and called the *notochord*, or *chorda dorsalis*. It is this structure which is subsequently developed and becomes the backbone.

Another singular condition is invariably presented in the development of every vertebrate, whether the structures formed are transitory or permanent.

This condition is the appearance of a certain series of openings formed at the side of the neck, and which in fishes remain permanent as the gill openings. These openings are termed *visceral clefts*, and lead from the exterior into the throat. The solid pillars (or intervals) between the clefts are called *visceral arches*, and in creatures (*e.g.* fishes) which develop gills upon them, *branchial arches*.

In all vertebrates again (unlike insects or spiders) there are never more than four limbs, and these are supported by bones, or cartilages, which are clothed externally with flesh, and are not moved by muscles placed *within* the hard parts, as is the case with lobsters, insects, and all their allies.

The heart in all vertebrates consists of at least two distinct cavities, and sends forth blood into a system of arteries, whence it is brought back again to the heart by other vessels termed the veins. On its way back to the heart, however, some of the veins carry blood to be redistributed in the liver, forming what is called the *portal* circulation.

In all the points above enumerated, the Frog (as we shall shortly see) fully agrees with beasts, birds, reptiles, and fishes, and thus shows that it differs from the immense majority of animals—the *Invertebrata*—and pertains unmistakeably to the seventh sub-kingdom of animals—the *Vertebrata.*

Now every sub-kingdom of animals is further divided into a greater or lesser number of subordinate (though still large) groups, termed *classes.* Each class is again subdivided into a certain number of smaller and more subordinate groups, each of which is termed an *order.* Each order is made up of *families,* each family being, of course, smaller and more subordinate than an order. Every family consists again of still more subordinate groups, each of which is termed a *genus.* And every genus comprises one or more *species.*

In zoology, every animal bears a name composed of two words. The first of these is a substantive, and denotes the genus to which any given animal belongs. The second word is an adjective—or a word used in an adjective sense—and denotes which species of the genus that given animal is. Thus the Chimpanzee is called *Troglodytes niger;* it is the species *Niger* of the genus *Troglodytes*, which genus contains also another species, namely, the Gorilla.

CHAPTER II.

BEFORE passing on to an enumeration of the subordinate groups of the sub-kingdom Vertebrata, we may first revert to our subject, the Frog, and make further acquaintance with it.

The common Frog of this country belongs to the genus *Rama*, and it is the species *Temporaria*, therefore its scientific name is *Rana temporaria*. It is common in Ireland, as well as in England and Scotland, and is indeed the most widely distributed species of the frog-order, being found throughout the north temperate regions of both the Old and New Worlds. It is found over nearly the whole of Europe; in Africa north of the Sahara, and in Egypt; in Northern Asia, including Japan and Chusan, and it is also spread over North America. It is not found in the northern half of Scandinavia, nor in Iceland.

Except in winter, the common Frog is generally in England so familiar an object, that any description of it might seem superfluous. The purpose in view, however, renders it needful at least to recall certain external structural characters both of the adult and the immature condition.

The head and body of the Frog together form an elongated oval mass, somewhat pointed at each end, of which mass the head constitutes rather more than one-third. This mass is more or less flattened both above and below, except at the commencement of the hinder third of the back, where there is a more or less marked prominence, which indicates the junction

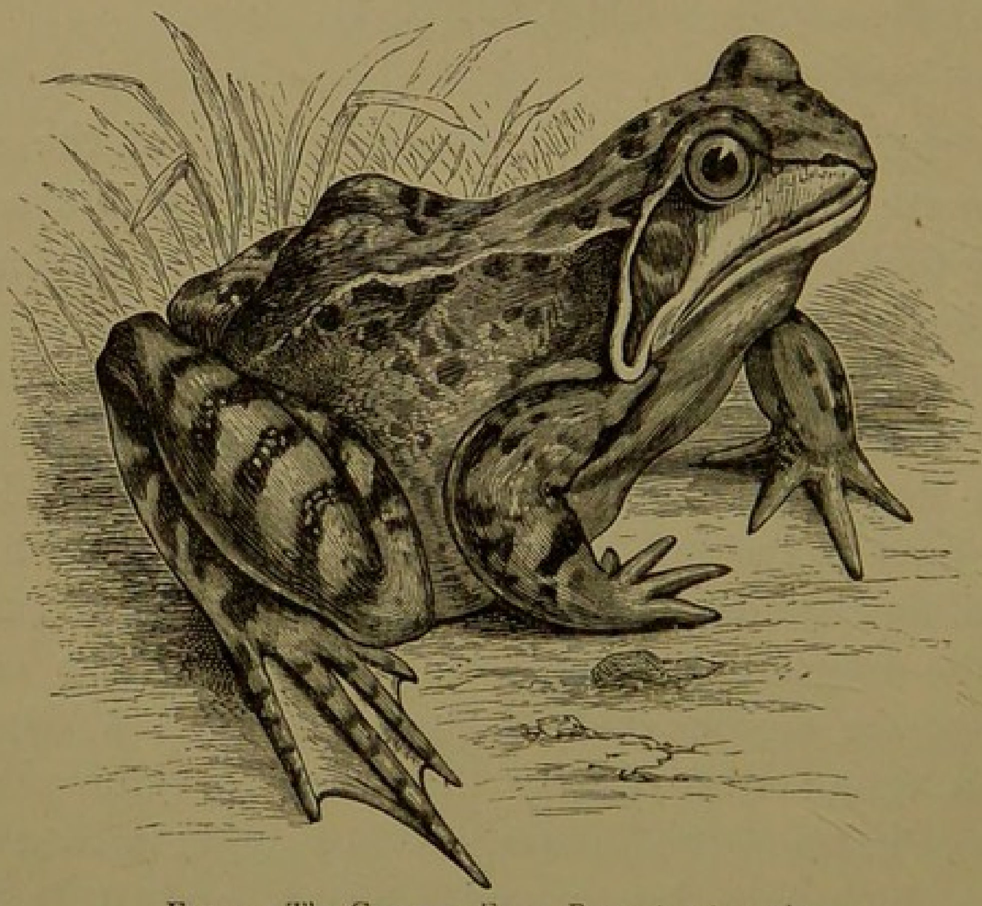

FIG. 1.—The Common Frog, *Rana temporaria*.

of the haunch bones with the spine. In front of this the only marked projections are those of the eyeballs.

The short arms project outward on each side just behind the head, and each ends in a small hand with four fingers, the second of which is the shortest, and the third the longest. When the arm is turned backwards this third finger barely attains (if it can do so at all) the hinder end of the body.

The hind limbs proceed from quite the hinder end of the body, there being no vestige of a tail. The thigh is very muscular, and the leg has a good "calf." The foot is exceedingly long and, what is very remarkable, is so jointed that the toes can be sharply bent upwards on its thick and undivided part. The latter thus seems to form a third segment of the hind limb following the thigh and the leg, the limb having thus four segments instead of three as in ourselves, and in almost all beasts, birds, and reptiles.

The foot ends in five toes connected by a web. Of these the fourth is the longest, the first the shortest. On the inner margin of the sole of the foot, at the root of the first toe, is a small, hard prominence, called a "tarsal tubercle." When the hind limb is turned forward, the knee reaches nearly to the armpit; the ankle-joint is about on a line with the end of the snout, and both parts of the foot are beyond it. These two parts of the foot together are much longer than the whole fore limb, and exceed two-thirds of the length of the whole mass of the head and body.

When the animal is viewed in profile, the point of the muzzle is seen to be very little in advance of the opening of the mouth. The latter is straight. It is also very wide, extending back even beyond the hinder margin of the eye. Just above the hinder angle of the gape, and behind the eye, is a rounded surface of smooth, tightly-stretched skin. This is called the "tympanum," and directly covers in the drum of the ear.

When the mouth is opened, if the finger be drawn along the inner margin of the upper jaw, a series of minute teeth may be detected. Towards the front of the palate are a pair of small holes (which are the inner openings of the nostrils), and between these are two juxtaposed little groups of other minute teeth. There are no teeth whatever in the lower jaw. At the hinder end of each side of the palate is another small hole. These latter two apertures are each the opening of a canal leading from the mouth to the cavity of the ear within the drum. The tongue is seen to be large, flat, and fleshy. It is tied down to the jaw in front, but free for more than its hinder half, with two processes developed from its free hinder margin.

The skin of the Frog is naked and smooth, without a trace of scales, or other appendages. Its colour on the upper surface is more or less yellowish, or reddish brown, with irregular black, brown, or grey patches. Similar patches form transverse bands upon the legs. Beneath, the colour is pale yellowish, often with a few spots, paler than those of the back. There is constantly a brownish black subtriangular patch placed behind the eye, and extending over the tympanum down towards the shoulder. The Frog breathes partly by swallowing air (aided by a mechanism to be described hereafter), partly by the direct respiratory action of the skin. It feeds exclusively upon living animals, such as insects and slugs, which it catches by suddenly throwing forwards beyond the mouth, the free hinder half of the tongue (furnished with an adhesive secretion), and then retracting it with its prey in a most rapid manner.

In winter the Frog passes into that torpid state known as *hibernation*, as is the case with our bats, hedgehogs, and some other beasts. Its season of torpidity is generally passed by it buried in mud and at the bottom of water, and great numbers of individuals may be dug up in winter all clustered together.

In spring the frogs again congregate for the purpose of oviposition in the month of March, at which period their well-known croaking makes itself heard, and though in itself unmelodious, possesses a certain charm through its association with the vernal outburst of nature.

When first laid, the Frog's eggs are little round dark bodies enclosed in no solid shell or case, but in a small glutinous envelope. The latter quickly swells in the water, so much so that the "spawn" comes to have the appearance of a great mass of jelly through which dark specks (the yolks of the egg) are scattered. Each egg, when microscopically examined, may be seen to undergo a process of yolk subdivision and cleavage till a mulberry-like mass is formed. Upon this soon appears the "primitive groove," which forms a canal and develops beneath it a "chorda dorsalis" according to the process which has been already stated to be common to the whole of the Vertebrata.

Gradually the embryo assumes the form of a young tadpole, and is provided with a pair of little "holders" (or organs for adhesion) just behind the mouth, with six openings on each side of the neck (Fig. 2, cl^1–cl^6), and with a pair of rudimentary external gills (Fig. 2, *br*[1] and *br*[2]). These openings are termed "visceral clefts," which lead from the exterior into the throat, as already described. The solid pillars (or intervals) between the clefts, *i.e.*, the "visceral arches," become furnished with gills,[1] or *branchiæ*, and are therefore

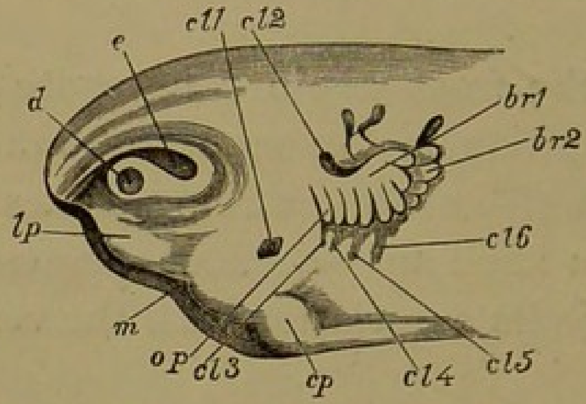

FIG. 2.—View of left side of Embryo Tadpole (after Parker). *br*[1] and *br*[2], first and second external branchiæ; *cl*[1]—*cl*[6], the six visceral clefts; *cp* the left "holder"; *d*, the olfactory organ; *e*, the eye; *lp*, the left lip; *m*, the aperture of the mouth; *op*, the hinder margin of the rudimentary operculum.

called "branchial arches." The eggs are hatched towards the end of April, and the tadpole emerges in the stage represented at Fig. 3, 1. It has a relatively large head, a rounded body, and a long tail, by lateral undulations of which the little creature swims about. From behind the head, on each side, jut forth external branchiæ as a small plume-like structure, but no limbs are visible.

As the tadpole grows, the external plumose gills at first greatly enlarge (Fig. 3, 2 and 2*a*), but afterwards become gradually absorbed, and are succeeded by short gill filaments, which are developed along each of the branchial arches. These latter filaments

[1] Gills (or branchiæ) are delicate processes of skin richly supplied with minute blood-vessels, wherein the blood becomes exposed to the purifying action of the air dissolved in the water.

do not appear externally, and indeed a membrane, termed the operculum (Fig. 2, *op*), is developed from the front of each series of branchial apertures,

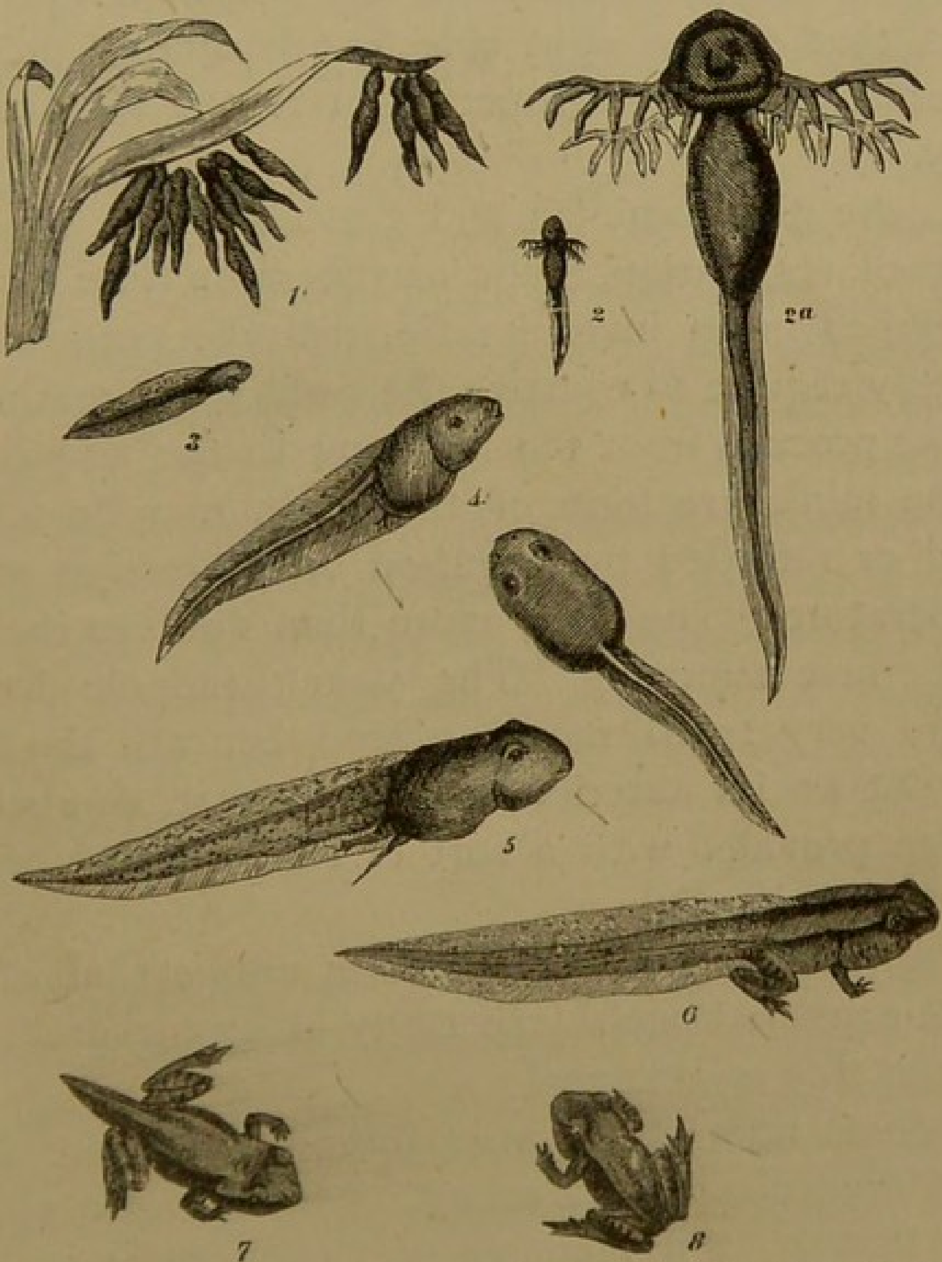

FIG. 3.—Tadpoles in different stages of development, from those just hatched (1) till the adult form is attained (8).

and which, extending backwards by degrees, ultimately covers over and conceals them.

Little by little the limbs bud forth and grow, the hind ones being the first visible because the fore limbs are for a time concealed by the opercular membrane. As the legs grow, the tail becomes absorbed (Fig. 3, 7), not falling off, as some suppose. The gills also disappear, and the branchial apertures close, that on the right side first becoming obsolete by adherence of the operculum to the skin of the body.

As the gills diminish and cease to serve the purposes of respiration, lungs at the same time become developed in an inverse ratio, and the tadpoles absolutely require to come to the surface to breathe.

The process, from the hatching to the acquisition of the miniature form of the adult, may be accelerated or retarded by elevation or depression of the temperature. The Frog more than doubles its bulk in its first summer.[1] The young tadpole has at first a very small mouth placed beneath the head and not at its anterior termination; it is also for a time provided with a sort of beak formed of two little horny jaws.

The food of the tadpole, quite unlike that of the adult, consists largely (especially in its earlier stages) of vegetable substances.

Having now made acquaintance with the Frog considered absolutely, or by itself, and also clearly seen that it is a member of the Vertebrate Sub-kingdom, we may enumerate the principal primary subdivisions (Classes) of that sub-kingdom, and enumerate such of the next smaller groups (Orders) as more or less nearly concern the subject of this work—the Frog.

[1] Parker, Phil. Trans. 1871, p. 172.

The Vertebrata are divided into five great Classes:—(I.), *Mammalia* (Man and Beasts); (II.), *Aves* (Birds); (III.), *Reptilia* (Reptiles, *i.e.* Crocodiles, Lizards, Serpents, and Tortoises); (IV.), *Batrachia* (Amphibians, *i.e.* Frogs, Toads, Efts, &c.); and (V.) *Pisces* (Fishes).

Of these five classes Birds and Reptiles are classed together in a larger group called *Sauropsida*, because they present so many structural resemblances. Similarly Amphibians and Fishes are grouped together, and to their united mass the common term *Ichthyopsida* is applied.

The orders into which the two classes, Mammalia and Aves (beasts and birds), are divided, may here be neglected, as we shall have little to say respecting them in the following pages. There are, however, about twelve orders of beasts, and probably some fourteen of birds.

The class of Fishes has been subdivided into five Orders.

1. Elasmobranchii (the sharks and rays, or highly organised cartilaginous fishes).

2. Ganoidei, an important order, containing many extinct forms, and a few very varied existing ones, such as the mud-fish (Lepidosiren), Ceratodus, and the sturgeon.

3. Teleostei, the ordinary or bony fishes, such as the carp, sole, perch, &c., and containing a remarkable group called Siluroids, as also the curious little sea-horse—Hippocampus.

4. Marsipobranchii (the lamprey and myxine, or lowly organised cartilaginous fishes).

C 2

5. Pharyngobranchii (the amphioxus, or lancelet).

Reptiles are arranged in nine different orders, five of which are now entirely extinct. They are of living forms:—

1. Crocodilia (crocodiles).

2. Sauria (lizards, the Amphisbenæ, the little Flying-dragon, &c.)

3. Ophidia (serpents).

4. Chelonia (tortoises and turtles).

Of extinct kinds there are:—

5. Ichthyosauria; 6, Plesiosauria; 7, Dicynodontia; 8, Pterosauria; and 9, Dinosauria.

The remaining class, Batrachia, will require more lengthy consideration, both as a whole and as regards the four orders which compose it, and which are called respectively, 1, Anoura; 2, Urodela; 3, Ophiomorpha; and 4, Labyrinthodonta.

It will require such consideration, because it is the class to which the Frog itself belongs.

The Frog belongs to the Batrachian order *Anoura*, to the family *Ranidæ*, and to the genus *Rana*.

The order Anoura, to which all frogs and toads belong, is a remarkably homogeneous one, consisting as it does of a multitude of species, all differing from each other by comparatively trifling characters.

Altogether there are about 600 species of frogs and toads, arranged in about 130 different genera.

CHAPTER III.

TO prosecute successfully our inquiry "What is a Frog?" it will be well now to make acquaintance with the more remarkable forms contained in its *Order*, after which, by considering the other Batrachian orders, we may arrive at a certain appreciation of its *Class*.

The Frog's own genus (Rana), which contains about 40 species, has its head-quarters in the East Indies and in Africa, but extends over all the great regions of the world, except Australia and parts more southerly still and except countries situate above 66° north latitude. In South America, however, but a single species is as yet known to exist.

Amongst the largest species are *Rana tigrina*, of India, and the Indian Archipelago, and the bull-frog (*R. Mugiens*) of North America. The latter animal may often be seen in the Gardens of the Zoological Society, where it is fed on small birds—a sparrow being easily engulphed within its capacious jaws.

The Edible Frog, *par excellence* (*R. esculenta*), is found in England as well as on the Continent of Europe. It is as widely distributed over the Old World as is *R. temporaria,* but it is unknown in America. It is easily to be discriminated from the common species by the absence of that dark, sub-triangular patch which extends backwards from the eye in *R. temporaria.*

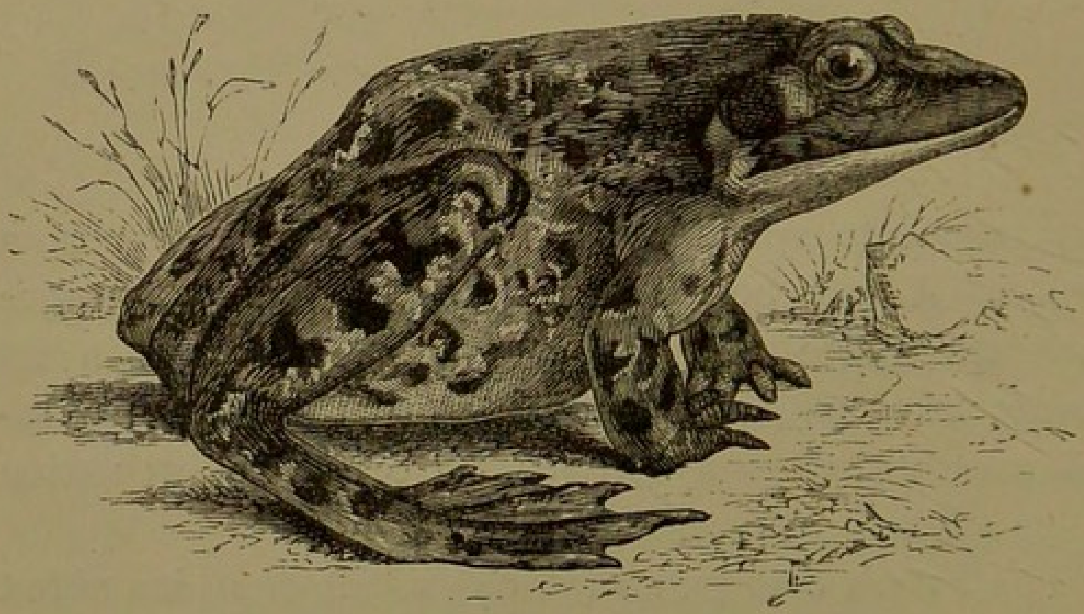

FIG. 4.—The Edible Frog (*Rana esculenta*).

The male of *R. esculenta* is further to be distinguished from the male of the common Frog by the fact of its having the floor of the mouth, on each side, distensible as a pouch—the pouches, when distended, standing out on each side of the head. These pouches are called "vocal sacs," and no doubt aid in intensifying these animals' croak, which is so powerful that (on account of it and because of the country where they are common) they have been nicknamed "Cambridgeshire Nightingales." Specimens from Cambridgeshire are preserved in the British Museum.

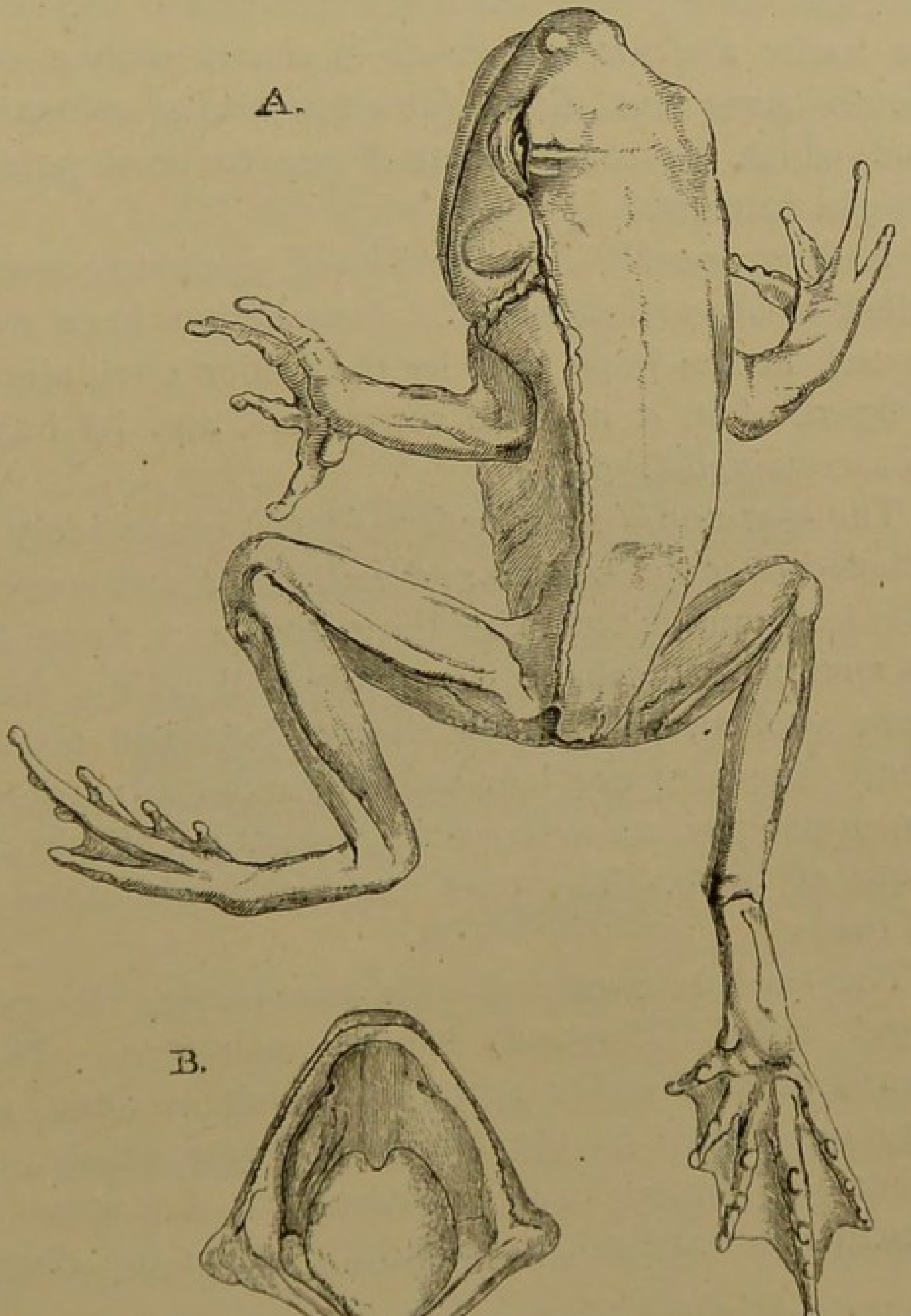

FIG. 5.—A, *Clinotarsus robustus*, nat. size; B, interior of the mouth of ditto.

A large South American Frog (*Ceratophrys cornuta*), which devours other smaller Frogs as well as small birds and beasts, is noteworthy on account of the singular bony plates which are enclosed in the skin of its back: a character which it shares with a small South American Toad (*Brachycephalus ephippium*), and which we shall hereafter see to be a point of special interest.

A Frog newly discovered[1] (of a new genus but allied to *Rana*), called *Clinotarsus*,[2] has been represented, in the hope that by the wider circulation of a figure of it, it may be recognized, and its habitat so ascertained (Fg. 5).

The common Toad (*Bufo vulgaris*) is as widely distributed over the earth's surface as is *Rana esculenta*. It is less aquatic than the Frog, and more sluggish in its motions. In shape it resembles the Frog, but is more swollen, with much shorter legs and a warty skin. The toes are less webbed, and the margin of the upper jaw, as well as the lower, is entirely destitute of teeth. The jaws are similarly toothless in *all* toads.

The toad is provided with an oblong, elongated gland called (*Parotoid*) behind each eye. These glands emit a milky secretion which is acrid and very unpleasant to the mouth of some carnivorous animals. Those who have observed a dog attacking a toad can hardly have failed to notice the disgust

[1] The type of this genus is a species which was in my own collection (with no clue to the locality whence it originally came), but is now deposited in the British Museum. It was first described in the Proceedings of the Zoological Society for 1868, under the name *Pachybatrachus*.

[2] Proc. Zool. Soc., 1869.

which the former animal seems to exhibit by the copious flow of its saliva, its many head-shakings, &c. The toad's secretion, however, cannot be said to be poisonous, and certainly it is not so in the mode in which the venom of serpents is poisonous, since a chicken may be inoculated with it, and yet appear to suffer no injury whatever beyond the infliction of the slight wound necessary for the performance of the operation. Nevertheless the secretion

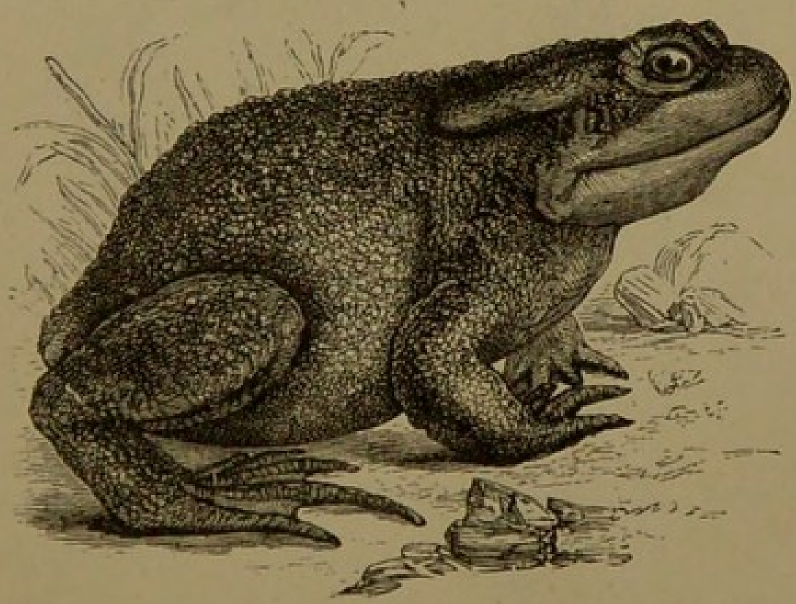

FIG. 6.—The Common Toad (*Bufo vulgaris*).

exercises a very decided effect upon certain animals, since the tadpoles both of frogs and of salamanders are very powerfully affected by being kept in the same water with a toad, if the latter be specially irritated in order to make it discharge its pungent and irritating secretion.

True poison and organs fitted both to inflict wounds and to convey the venom into them are not indeed found in any animals which are even near allies of the frogs and toads. Nevertheless a very perfect organ for both wounding and poisoning has been discovered by Dr. Günther to exist in a certain fish (*Thalassophryne reticulata*), belonging to a group

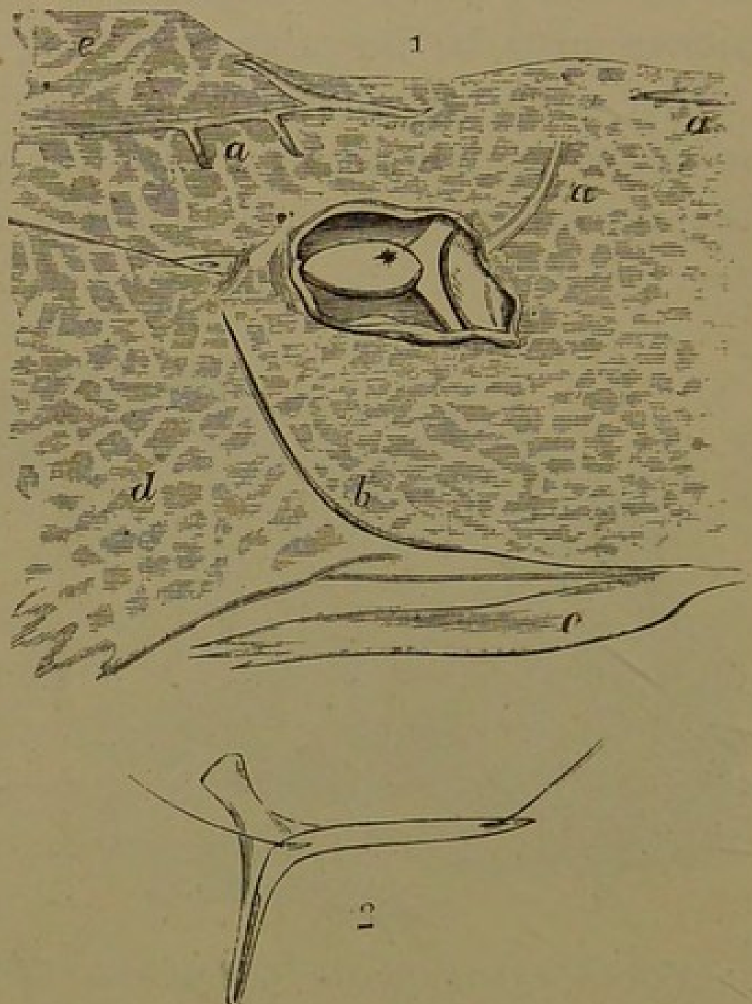

FIG. 7.—Poison Organ of *Thalassophryne reticulata* (after Günther). 1, Hinder half of the head with the venom-sac of the opercular apparatus *in situ*. * Place where the small opening in the sac has been observed. *a*, Lateral line and its branches; *b*, gill-opening; *c*, central fin; *d*, base of pectoral fin; *e*, base of dorsal fin 2, Operculum, with the perforated spine.

which, on account of their superficial resemblances to frogs, are termed "Batrachoid."

He found in the fish no less than four spines, each perforated like the tooth of a viper, and each having a sac at its base. One such poison-spine was situated on each side of the hinder part of the head in front of the gill-opening. Two others were dorsal spines placed one behind the other on the mid-line of the back. These poison-organs are probably only used for defence. They are formed, however, on the very same type as are the poison fangs of vipers. Unlike the latter, however, they are not modified teeth, nor

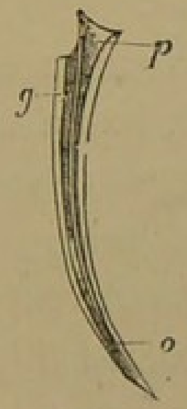

FIG. 8.

FIG. 9

FIG. 8.—Vertical, Longitudinal Section of the Poison-fang of a Serpent (after Owen). *g*, deep groove; *o*, its lower termination, which affords exit to the poison; *p*, pulp-cavity. FIG. 9—Magnified Transverse Section of a Serpent's Poison-fang (after Owen). *g*, groove round which the substance of the tooth (containing *p*, the pulp-cavity) is bent; *j*, the point where the sides of the tooth meet and convert the "groove" into what is practically a central cavity.

are they situated within the mouth as they always are in poisonous serpents.

A Frog (*Pelobates fuscus*) which is common in France (and which is interesting on account of the form of its skull hereafter to be pointed out), though really harmless enough, has a singular power of making itself offensive.

Both males and females of this species utter a kind of croak, and both, if the thigh is pinched, produce a sound like the mewing of a cat. At the same time they emit a strong odour, which is like that of garlic, and becomes stronger as the animals are more disturbed. This emission not only affects the sense of smell, but even makes the eyes water as mustard or horseradish does.

This singular power, together with the acrid secretion of the toad, are the nearest approximation to venomous properties possessed by any members of the order, no toad—not even the giant of the order *Bufa agua*—being really poisonous.

A small Frog, by no means uncommon in France and Germany (*Alytes obstetricans*), has a very singular habit. The female lays its eggs (about sixty in number) in a long chain, the ova adhering successively to one another by their tenacious investment. The male twines this long chaplet round his thighs, so that he acquires the appearance of a courtier of the time of James I. arrayed in trunk hose and puffed breeches. Thus encumbered, he retires into some burrow (at least during the day) till the period when the young are ripe for quitting the egg. Then he seeks water, into which he has not plunged many minutes when the young burst forth and swim away, and he, having disencumbered himself of the remains of the ova, resumes his normal appearance.

Certain Frogs (forming a very large group) are termed Tree-Frogs, from their adaptation to arboreal life by means of the dilatation of the ends of the digits into sucking discs, by which they can adhere to leaves. One of them, the common green Tree-Frog (*Hyla arborea*), is spread over Europe, Asia, and Africa, in the same manner as *R. esculenta*, except that it is not found in the British Isles. A few toads also have the tips of their digits similarly dilated. Such, *e.g.*, is the case with the genera *Kaloula* of India, and *Brachymerus* of South Africa.

The female of a peculiar American Tree-Frog (*Nototrema marsupiatum*) has a pouch extending over the whole of the back and opening posteriorly.

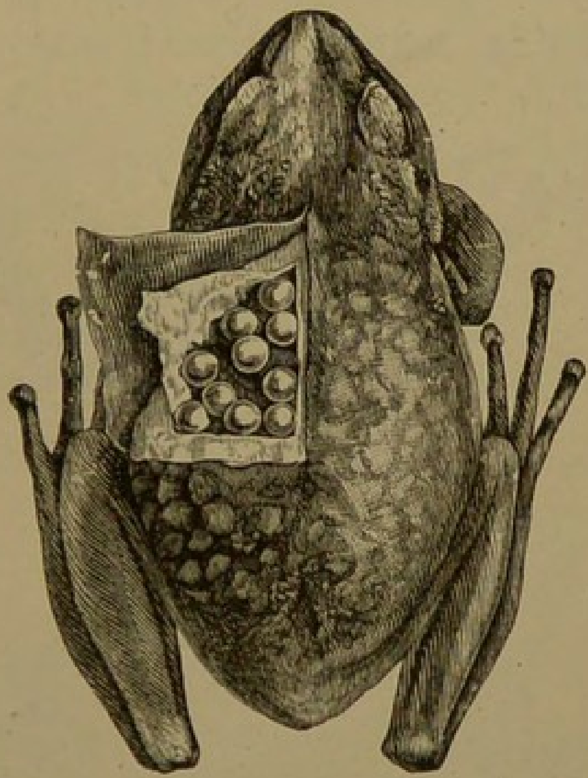

FIG. 10.—The female of *Nototrema marsupiatum*, with the pouch partly cut open (after Günther).

Into this the eggs are introduced for shelter and protection. A dorsal pouch also exists in the allied American genus, *Opisthodelphys*. An American species of *Hylodes* has the habit of laying its eggs in trees singly in the axils of leaves, and the only water they can obtain is the drop or two which may from time to time be there retained.

A still more remarkable mode of protecting the egg is developed by the Great Toad of tropical America (*Pipa americana*). In this case the skin of the female's back at the laying season thickens greatly and becomes of quite a soft and loose texture. The male, as soon as the eggs are laid, takes them and imbeds them in this thick, soft skin, which closes over them. Each egg then undergoes its process of development so enclosed, and the tadpole stage is, in this animal, passed within the egg, so

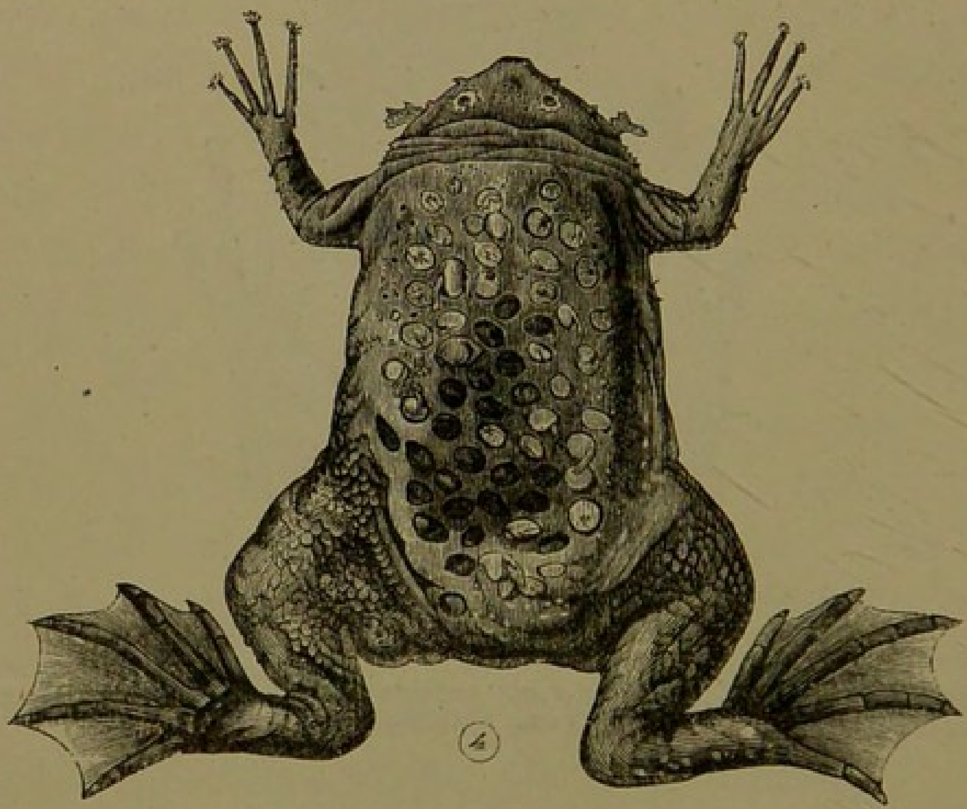

FIG. 11.--The Surinam Toad (*Pipa americana*).

that the young toads emerge from the dorsal cells of the mother completely developed miniatures of the adult. As many as 120 of these dorsal cells have been counted on the back of a single individual.

The only instance of a similar cutaneous modification is that pointed out by Dr. Günther[1] in the

[1] See Catalogue of the Fishes in the British Museum, vol. v. p. 268.

skin of the belly of the Siluroid fish, *Aspredo batrachus.* Here he found that "the whole lower surface of the belly, thorax, throat, and even a portion of the pectoral fins, showed numerous shallow, round impressions, to which a part of the ova still adhered." He concludes that "it is more than probable that towards the spawning time the skin of the lower parts becomes spongy, and that, after having deposited the eggs, the female attaches them to it by merely lying over them." "When the eggs are hatched the excrescences disappear, and the skin of the belly becomes smooth as before." Even in the highest class of animals (*Mammalia*) we are familiar,

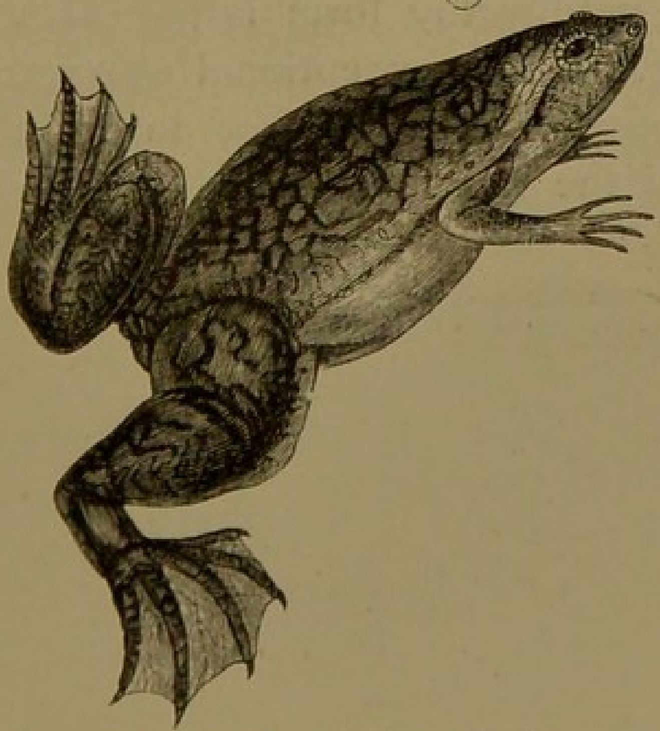

FIG. 12.—*Dactylethra capensis.*

in the Kangaroo and Opossum order (*Marsupialia*), with a special external receptacle (the marsupial pouch) for the protection and secure development of the young; but nothing of the kind exists amongst birds or reptiles. In fishes, however, the male of the little Sea-horse (*Hippocampus*) is provided with a ventral pouch in which the eggs are sheltered, and the same class presents us with a mode of carrying the eggs still more bizarre than that of *Alytes obstetricans* just related. In the fish *Arius fissus* the male actually carries about the ova in the mouth, protected by the jaws, till relieved of the inconvenience by the hatching of the young fry.

A South African Toad (*Dactylethra capensis*) is interesting, as we shall hereafter see, on account of certain anatomical points in which it agrees with *Pipa*, and differs from all other Anoura. No interesting facts, however, are known as to its habits.

Another noteworthy form is the Mexican *Rhinophrynus dorsalis*, the exceptional characters of which are the tongue, which is free in front instead of behind, and the enormous spur-like tarsal tubercle.

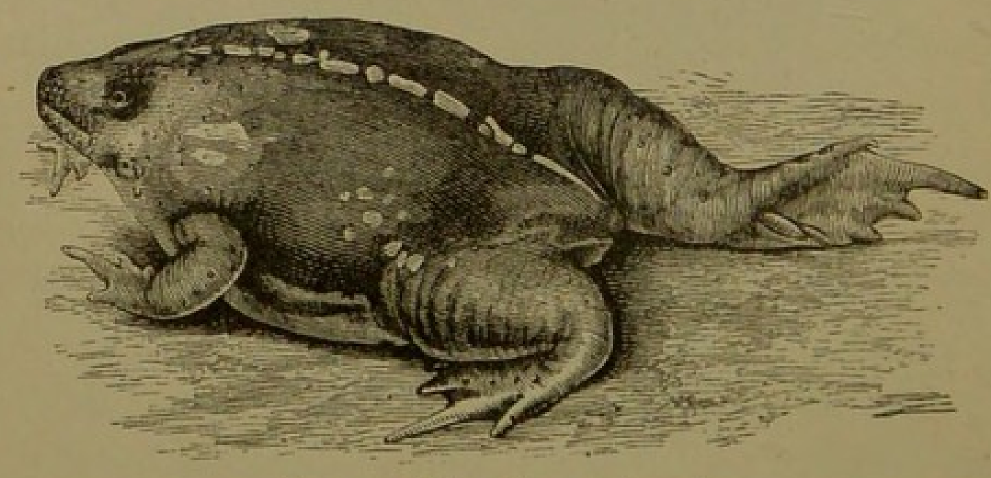

FIG. 13.—*Rhinophrynus dorsalis.*

Almost all frogs and toads pass the first stages of their existence in water, going through a free, tadpole stage, and all are more or less aquatic when adult. The only exceptions are *Pipa*, *Nototrema*, *Opisthodelphys*, and the *Hylodes* before referred to. Very many kinds, however, are, when adult, inhabi-

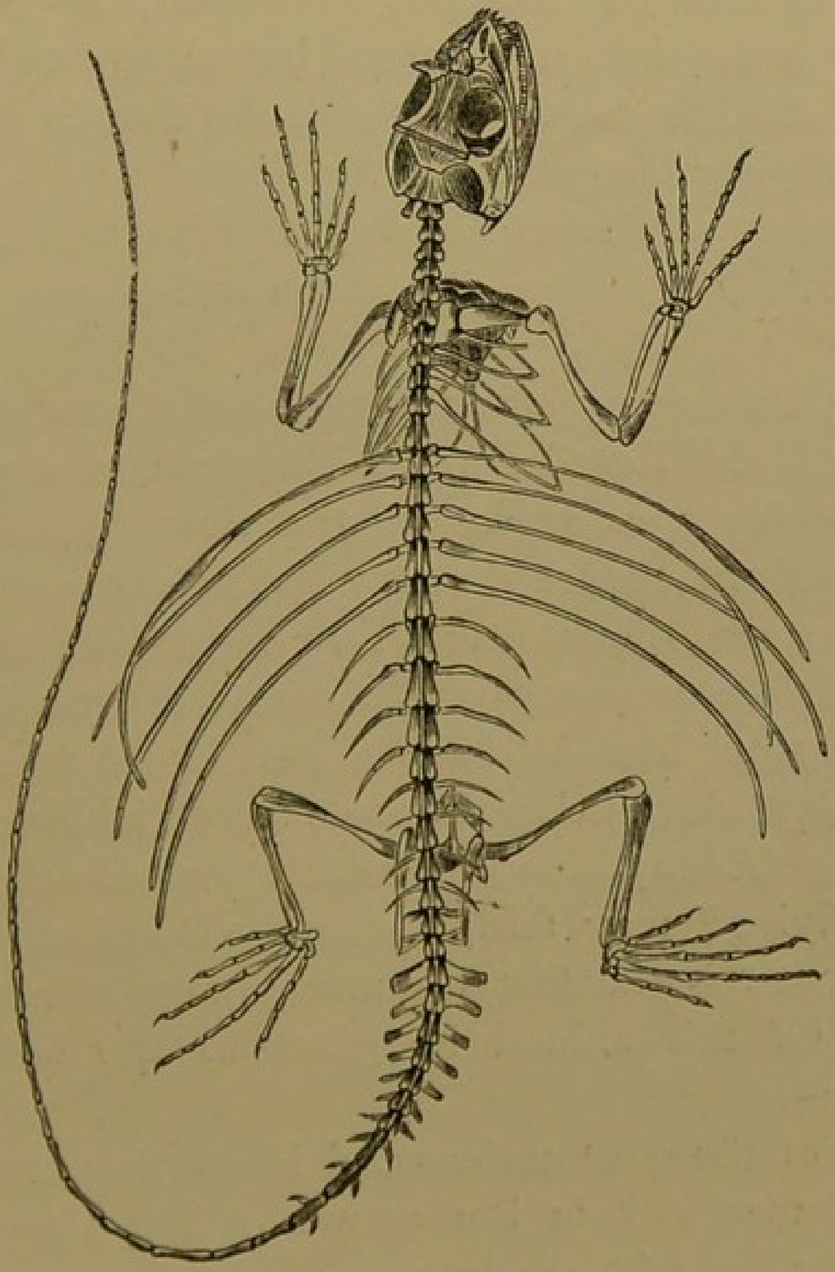

FIG. 14.—Skeleton of the Flying Dragon.
(Showing the elongated ribs which support the flitting organ.)

tants of trees. The question may suggest itself to some, "Are there any which can be said in any sense to be aërial animals?" Birds are almost all capable of true flight, as also are those aërial existing beasts the Bats, and as were those extinct reptiles the Pterodactyles. Certain squirrels and opossums can take flitting jumps by means of an extension of the skin of the flank, and a similar, though much greater extension, supported by elongated freely ending ribs, is found in the little lizards (*Draco*) called Flying Dragons.

The class of Fishes supplies us, also, with an example of aërial locomotion in the well-known Flying Fish.

Since, then, every other class of vertebrate animals (Beasts, Birds, Reptiles and Fishes) presents us with more or fewer examples of the aërial species, we might perhaps expect that the Frog class would also exhibit some forms fitted for progression through the air. We cannot say with certainty that such is the case; but Mr. Alfred Wallace, in his travels in the Malay Archipelago, encountered in Borneo a Tree-frog (*Rhacophorus*) to which he considers the term "flying" may fairly be applied, and of which he says, it "is the first instance known of a flying-frog." Of this animal he gives us the following account:—

"One of the most curious and interesting creatures which I met with in Borneo was a large tree-frog which was brought me by one of the Chinese workmen. He assured me that he had seen it come down, in a slanting direction, from a high tree as if it flew. On examining it I found the toes very long and fully webbed to their extremity, so that, when expanded, they offered a surface much larger than the body. The fore-legs were also bordered by a membrane, and the body was capable of considerable inflation. The back and limbs were of a very deep shining green colour, the under surface and the inner toes yellow, while the webs were black rayed with

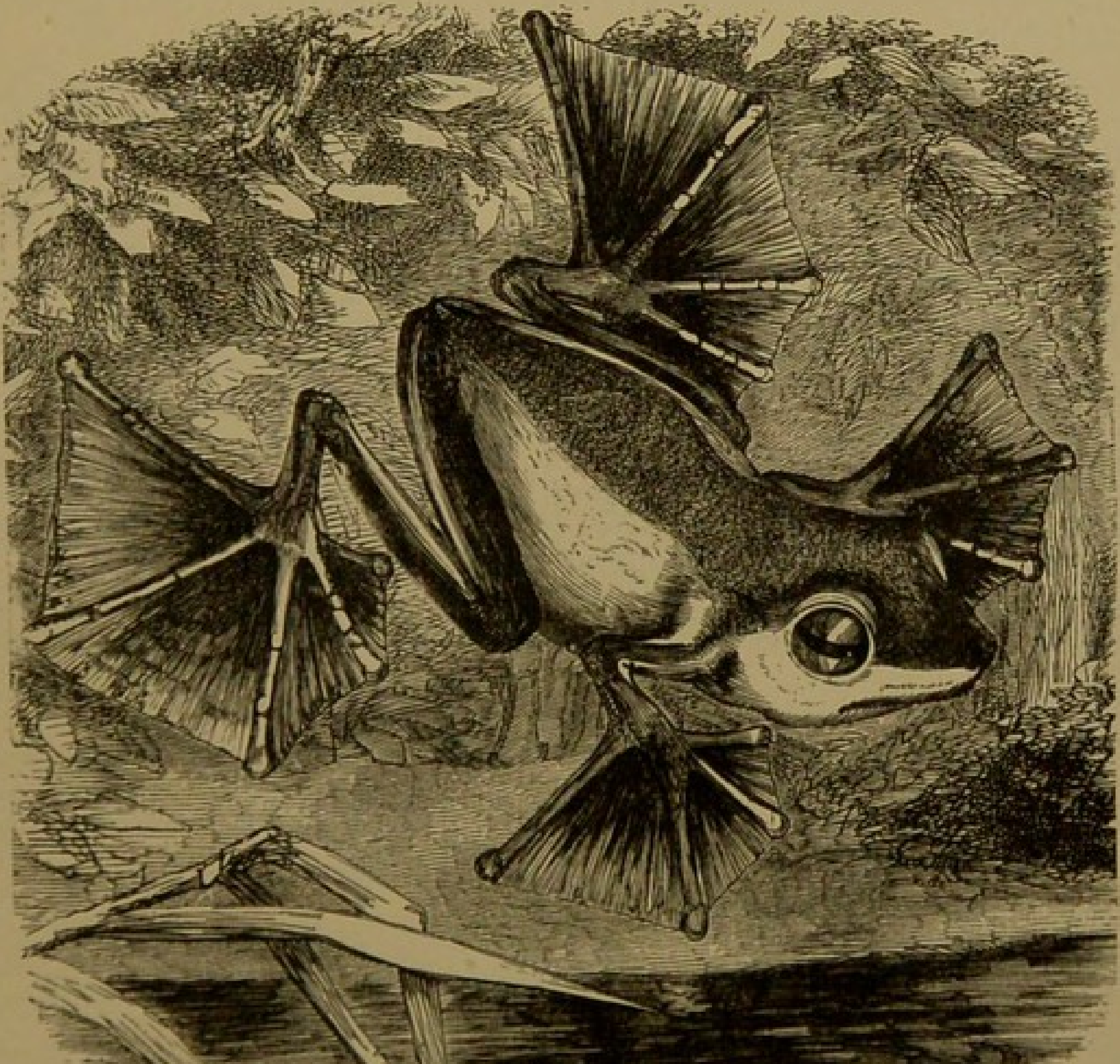

FIG. 15.—The Flying Frog (from Wallace's "Malay Archipelago").

yellow. The body was about four inches long, while the webs of each hind foot, when fully expanded, covered a surface of four square inches, and the webs of all the feet together about twelve square inches. As the extremities of the toes have dilated discs for adhesion, showing the creature to be a true Tree-frog, it is difficult to imagine that this immense membrane of the toes can be for the purpose of swimming only, and the account of the Chinaman that it flew down from the tree becomes more credible."

The great group of Frogs and Toads, rich as it is in genera and species, and widely as it is diffused over the earth's surface, is one of singular uniformity of structure. The forms most aberrant from our type, the common Frog, have now been noticed, except that perhaps the maximum respectively of obesity and slenderness may be referred to. In the former respect the Indian Toad, *Glyphoglossus*, may serve as an example, and for the latter may be selected *Hylorana jerboa.*

CHAPTER IV.

HAVING now passed in review the greatest differences presented by the nearest allies of our common Frog (the members namely of its own order), certain facts of interest present themselves respecting the geographical distribution of the group Anoura. These facts are interesting, because they point not only to the exceptional nature of the faunas of South America and of Australia, but also to a certain zoological affinity between those two regions of the earth, distinct as they are from one another. Thus, as has been mentioned, it is only in Australia and South America that the typical genus *Rana* is absolutely wanting. One genus of Tree-frogs, *Pelodryas,* is confined to Australia, but is closely resembled by another genus, *Phyllomedusa,* which is restricted to South America, and differs from the former only by the absence of a web between the toes. It should be recollected that the primary subdivisions of a zoological order are termed *families.* One whole family, called *Cystignathidæ,* is (with the exception of two species) confined to Australia and America.

The typical Tree-frogs (*Hyla*) abound in South

America and are also found in Australia, but not in India or in Africa south of the Sahara. On the other hand, another genus of Tree-frogs (*Polypedates*), is found in India, Japan, and Madagascar, but not in either Australia or America.

The typical Toads (*Bufo*) have, however, their head-quarters in South America, yet are wanting in Australia, though they are found everywhere else where the order exists at all.

The earth's surface, considered as to its population of the Frog and Toad order, may be divided into three great regions. The first of these is composed of Europe, Northern Asia (with Japan and Chusan), North America, and Africa north of the Sahara. The second region consists of Africa south of the Sahara, Madagascar, India, and the Indian Archipelago. The third region is made up of South America and Australia, and the resemblance between these two parts of the earth's surface as to their frogs and toads is paralleled by that as to their mammalian faunas, since marsupial mammals (or pouched-beasts of the opossum kind), are strictly confined to Australia (and its islands) and America.

No frog or toad has yet been found in New Zealand.

Africa, considering its size and climate, is poor in species of *Anoura*.

We should be prepared for the fact that in South America Tree-frogs abound, since all kinds of animals in that region assume an arboreal habit.

Monkeys are tree-livers all the world over, but nowhere are all the indigenous species so thoroughly arboreal as in tropical America. There alone do we find monkeys with a prehensile tail capable of serving as a fifth hand, and so affording greater security and facility to locomotion amidst the branches. Only there also do we find beasts so exclusively constructed to pass the whole of their lives in trees that they can move along the ground only with difficulty—such is the case with the sloths. Porcupines, which in the Old World have short tails, in the New World have long and prehensile ones. An animal allied to the Badger —the Kinkajou (*Cercoleptes caudivolvulus*)—similarly acquires in South America a long and prehensile caudal appendage. Even the Fowl and Peacock Order of Birds becomes in South America more strictly arboreal than elsewhere (being represented by the Curassows) ; and the very geese find there a congener (*Palamedea*) specially adapted to dwell in trees, and destitute (like the Frog *Phyllomedusa* before mentioned) of a web-like membrane between the toes.

We have now advanced a further stage in seeking a reply to the question, "What is a Frog?" We have also viewed it in the light to be derived from a consideration of the more noteworthy forms of the Frog's order.

We may next inquire what are its next nearest allies? What other animals of the class Batrachia constitute an order which approaches nearest to the Frog's order *Anoura?*

Almost every pond in England which harbours frogs, harbours also those little four-legged, long-tailed, soft-skinned creatures termed *Efts* or *Newts* (of the genus *Triton*) familiar to every schoolboy.

These Newts, which are thus by circumstances placed actually in juxtaposition with the Frog, are also zoologically his nearest allies outside his own (Frog and Toad) order. Like the Frog they undergo a metamorphosis, at first appearing as Eft-tadpoles (with elongated external gills, but devoid of limbs), subsequently losing the gills and acquiring limbs. Efts, as is manifest, are widely and strangely different in form from frogs and toads.

Thus is justified the assertion before made as to the far less exceptional form of the human body than that of the Frog. For when, amongst Mammalia, we go outside that *order* to which Man belongs, we find in his *class* other creatures (insect-eating, flesh-eating, and of the squirrel kind) which more or less closely resemble some of the lower members of man's order. When, however, amongst Batrachia, we go outside that *order* to which the Frog belongs, we find in his *class* no creatures whatever which present anything like such an approximation to any members of the Frog's order as is presented by the mammals above referred to certain members of man's order.

The Efts (or Newts) with their allies—hereinafter noticed—constitute the second order *Urodela* of the class Batrachia.

This order is very unlike the first and already described order (*Anoura*), in that it is composed of creatures which in many respects are strangely divergent; and though most of the species more or less resemble our own Efts (or Newts) in shape, yet the *Urodela* are very far from constituting such a homogeneous group as do the *Anoura*.

FIG 16.—An American Eft of the genus *Amblystoma*.

It will be well now to review some of the more striking forms contained in the order.

The Land Eft (*Salamandra*), though common in Holland and France (as well as the rest of Europe), is unknown in this country.

Genera allied to the European genera *Triton* and *Salamandra*, and to the American genus *Amblystoma*, may have the body and tail more and more elongated and the legs reduced, as in *Spelerpes, Chioglossa*, and *Œdipina*, till they attain the condition of *Batrachoseps*. The greatest excess of this development, however, is found in the North American genus *Amphiuma*, the minute limbs of which have either three or two toes, according to the species. These creatures are called by the negroes "Congo Snake," and are quite erroneously regarded as venomous (fig. 17).

The largest existing Urodele—the gigantic Salamander (*Cryptobranchus*)—is found in Japan, where it attains a length of 5 or 6 feet. A closely allied species inhabits China, and during the tertiary period one also inhabited Europe, the fossil skeleton of which being strangely supposed to be that of an antediluvian man received the curious appellation, "Homo diluvii testis."

In *Cryptobranchus* (as in all the Urodela yet enumerated except *Amphiuma*), though the young have gill-openings and external gills, the adults are devoid of both.

In a North American genus, however (*Menopoma*), which, though smaller in size, closely resembles Cryptobranchus in figure, there is a permanent gill-opening, though the gills themselves disappear in the adult,

Fig. 17.—The *Amphiuma.*

Fig 18.—The *Proteus.*

and the same is the case with *Amphiuma*. Thus in these animals the metamorphosis is less complete.

In the subterranean caverns of Southern Austria (Carniola and Istria) is found the *Proteus*. This is an elongated Urodele, with slender limbs, and but two toes to each hind foot. Passing its whole life in perpetual darkness, it is blind and colourless, except the external gills, which are red. This animal retains during the whole of life not only the gill-aperture on each side, but also the external plumose gills which are transitory in the Anoura and in all the Urodela hitherto mentioned. Here then we first meet with an animal which may be said to be a permanent and persistent Tadpole, yet rather like an Eft-tadpole than like that of the Frog (fig. 18).

A North American Urodele, misnamed (for it is silent enough) *Siren*, also presents us with permanent external gills, and it offers another interesting resemblance to the tadpole of the Frog, in that it is furnished throughout life with a horny beak. It has also another remarkable character in which it stands alone in its class. Hitherto every relative of the Frog has had, like it, four limbs in the adult condition. In the Siren, however, we for the first time make acquaintance with a creature belonging to the class (though not to the *order*) of Frogs and Toads, which is devoid altogether of hinder (or pelvic) limbs, being in this respect like the whales and porpoises amongst beasts, and like the little lizard, *Chirotes*, amongst reptiles.

Another North American Urodele, *Menobranchus*, possesses throughout the whole of life both gill-openings and external gills. But it is furnished with

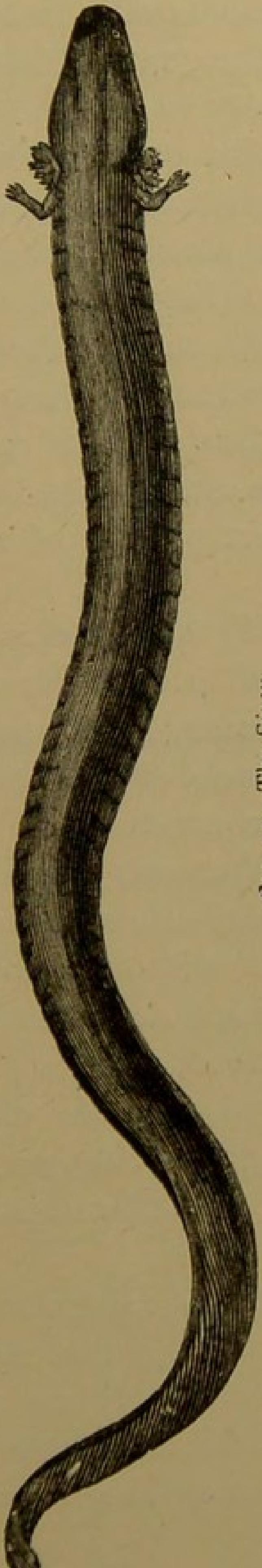

FIG. 19.—The *Siren*

FIG 20.—*Menobranchus.*

four limbs, and in other respects more or less resembles in appearance, as it does in size, the genus *Menopoma* before noticed.

Finally there is a genus of this order (*Urodela*) which has of late presented circumstances of peculiar interest. This is the Axolotl of Mexico, which was long considered by Cuvier to be a large Eft-tadpole, possessing as it does permanent gills and gill-openings, with some other characters common to the Eft-tadpole stage of existence. At length, however, its mature condition was considered to be established by the discovery that it possesses perfect powers of reproducing its kind.

For some years, individuals of this species have been preserved in the Jardin des Plantes at Paris, and a few years ago one individual amongst others there kept was observed, to the astonishment of its guardian, to have transformed itself into a creature of quite another genus — the genus *Amblystoma*, one rich in American species. Since then several other individuals have transformed themselves, but without affording any clue as to the conditions which determine this change—a change remarkable indeed, resulting as it does not merely in the loss of gills and the closing up of the gill-openings, but in great changes with respect to the skull, the dentition, and other important structures.

There is, moreover, another and very singular fact connected with this transformation. It is that no one of the individuals transformed (although we must suppose that by such transformation it has attained its highest development and perfection) has ever yet reproduced its kind, and this in spite of every effort made to promote reproduction by experiments as to diet, and as to putting together males and females both transformed, also transformed males with females untransformed, and males untransformed with females transformed. Indeed, the sexual organs seem even to become atrophied, in these transformed individuals. Moreover, all this time the untransformed individuals have gone on bringing forth young with the utmost fecundity, no care or trouble on the part of their guardians being required to effect it.

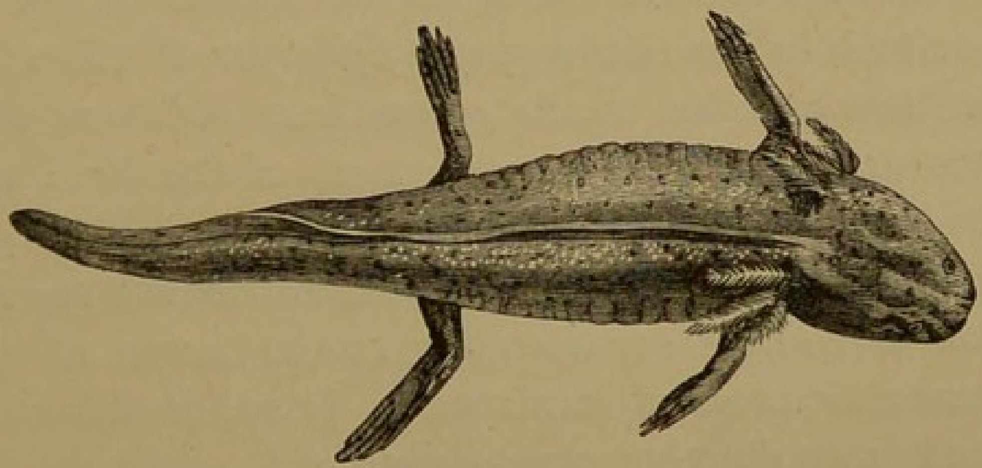

FIG. 21.—The Axolotl.

A fact more noteworthy could hardly be imagined in support of the view of specific genesis put forward recently.[1] Here we have a rapid and extreme transformation, taking place according to an unknown internal law of the species which transforms itself. No one, moreover, has been able to detect the conditions which determine such transformation (though it takes place under the eyes, and in the midst of the experiments, of its observers). This latter fact affords

[1] See "Genesis of Species," chap. xi.

abundant evidence how obscure and recondite may be the conditions which determine the transformations of specific genesis, and how utterly futile are observations as to an apparent homogeneity of readily appreciable conditions. They are so since it seems to be just such recondite ones which really determine the changes just referred to, and probably therefore, other changes analogous to them.

It may be a question whether the genus *Menobranchus* may not also be a persistent larval [1] form, and one which now never attains its adult form. If so, it is most probable that its lost state was similar to that of the exclusively American genus *Spelerpes*, the larva of which *Menobranchus* much resembles. With respect to *Proteus* and *Siren* no conjecture of the kind can yet be made.

Individuals belonging to the common English species (*Triton cristatus*) occasionally retain some of the external characters of immaturity, in spite of having attained reproductive capability; and a European species (*Triton alpestris*) often matures the generative elements while still, as to external appearance, more or less in its tadpole stage of existence. The adult condition, however, is normally and generally attained by it.

The geographical distribution of the *Urodela* is very remarkable. North America is the head-quarters of the order, and, with rare and trifling exceptions, the whole are confined to the Northern hemisphere. The exceptions are certain forms which extend down the Andes into South America, and one or two species of

[1] The young of the Frog or Eft is called a larva.

Amblystoma, which similarly descend along the highlands of South-eastern Asia. Urodeles are absolutely wanting in Hindostan, Africa south of the Sahara, the Indian Archipelago, Australia, and New Zealand. As might be expected, that part of Asia which is nearest to North America, namely China and Japan, is the region of the old world most richly peopled by species of *Urodela*. Altogether the world's surface may be divided according to its Urodele population into three regions. The first will comprise Europe, Africa north of the Sahara, and North-western Asia. The second will include Japan and Eastern Asia. The third will be formed by North America, with a slight extension southwards into South America—a division by no means coinciding with that indicated by the *Anoura*.

The above two orders (*Anoura* and *Urodela*) comprise all the animals most nearly allied to the common frog, of all those within or outside its own order. There is, however, another small ordinal group of animals which remains to be here noted, because of all existing creatures they come nearest to the frog, after the *Urodela*.

CHAPTER V.

THE third order of the class *Batrachia* is made up of a few creatures the distribution of which is limited to the warmer regions of the earth, where one of the genera (*Cæcilia*) comprising the group is distributed over both hemispheres, being found in India, Africa, and South America. Two other genera (*Siphonops* and *Rhinatrema*) are exclusively American, while a fourth genus (*Epicrium*) is only found in Asia. The order is called *Ophiomorpha*. These creatures are singularly unlike the frog in external appearance, as they are entirely destitute of limbs and have quite the appearance of earthworms, because they are not only very long and slender, but have also a skin which is soft and naked (fig. 22). By earlier naturalists, and even by Cuvier, they were classed with snakes.

In spite of this striking dissimilarity between the *Ophiomorpha* and *Anoura*, the former are really more like frogs than they are like efts in one important respect. This is because, for all their elongated figure, the tail in them is quite rudimentary or altogether absent.

The *Ophiomorpha* would by many be supposed to present an analogy with serpents, from their long and elongated bodies, and from the utter absence of limbs.

There are, however, but very few snakes (the "roughtails" *Uropeltidæ* and the *Tortricidæ*) which have long bodies and very short tails.

It is rather the singular family of lizards, *Amphisbenidæ* (with one exception completely limbless) that the Ophiomorpha resemble.

These Amphisbenians have a softer skin than any other Saurians except chameleons. It is also marked in grooves which are arranged in transverse rings. They have an exceedingly short tail which is blunt, so that, the head being small, one end of the body is as large as the other.

The *Ophiomorpha* also have the body marked with numerous transverse grooves or rings; they are utterly devoid of limbs, and the head is scarcely, if at all, larger than the hinder end of the body.

These creatures burrow beneath the soil (which habit increases their resemblance to earthworms) and feed on worms and other small animals and mould.

To turn now to another aspect of our subject, let us consider the relations of the Frog to past time. If, extending our survey over the records of past epochs, we search the tertiary and all other rocks above the

FIG. 22.—*Cæcilia.*

Lias for fossil allies of our Frog, we shall (judging by what we yet know) fail to find any not at once referable to one or other of the three ordinal groups above enumerated.

Fossil frogs and toads have as yet only been found down to the miocene, the oldest being some found in the so-called "brown coal" which is not a carboniferous deposit at all. The remarkable thing, however, is that the difference between these oldest known Frogs and the existing forms is so very trifling. They are as complete and thorough frogs as any that live now.

Again, the fossil Urodeles similarly resemble their existing representatives, and no one extinct species exhibits characters in any way tending to bridge over the chasm which separates the *Urodela* from the *Anoura*.

When, however, we descend to the Lias, Trias, and Carboniferous rocks, we come upon a great variety of extinct species of animals evidently allied to those forming the three Batrachian classes already described. They form, however, an order by themselves, to which the term *Labyrinthodonta* has been applied, and thus our search into the past has brought us a rich and important harvest, and has introduced us to the fourth and last order belonging to the Frog class of vertebrate animals. The Labyrinthodonts were creatures with long tails and mostly two pairs of limbs, but these members were always relatively small with slender toes. Some species attained a greater size by far than does any existing Urodela, even the gigantic Salamander.

To what existing animals can these huge monsters be considered to have affinity? It is impossible to say that they in any way bridge over the chasm separating the Frogs from the Efts. They appear indeed to have been almost equally removed from both—for the possession of short limbs and a long tail (characters common to so many widely different animals) cannot be regarded as any good evidence of affinity.

It is not improbable that they find their nearest allies in the existing insignificant *Ophiomorpha.* The latter, though apparently naked, have minute scales imbedded in the skin and arranged in rings at intervals, and the skull is provided with certain extra ossifications. The Labyrinthodonts have similar extra, cranial ossifications, and though they have not rings of scales, the ventral region was protected by minute plates arranged in linear series converging inwards and forwards towards the middle line. Moreover, some forms appear to have been entirely devoid of limbs; at least no remnant of such parts has yet been discovered. Nevertheless the degree of development of the tail constitutes a marked distinction between the *Labyrinthodonta* and the *Ophiomorpha.*

Certain Labyrinthodonts had great formidable teeth in elongated jaws like those of crocodiles. Altogether these singular remains tempt us to speculate as to the succession of life upon this planet's surface. We know that as to the later secondary period that part in the life of the globe which is now played by beasts was then played by reptiles Instead of the existing bats, Pterodactyles of all sizes flitted through the air. The ocean was peopled not by whales and dolphins, these had not yet appeared, but by huge Ichthyosauri and Plesiosauri. Reptiles of huge bulk (Iguanodons, Megalosauri, Notosauri, &c. &c.) fulfilled the parts of herbivorous and carnivorous beasts, and altogether the Mammalian fauna of to-day was represented by analogous reptilian precursors (figs. 24, 25.)

May it not have been similar in yet older periods with regard to animals of the Frog class? We have seen the possibility of aërial locomotion in even the existing *Rhacophorus*. It is true that all existing Urodeles are fresh-water forms, but it may well be that marine creatures once bore the same relation to them as the great marine *Ganoid* fish fauna bears to the few existing Ganoids[1] which now constitute a fresh-water group.

The great crocodile-like Labyrinthodonts must have been no ignoble predecessors of the rapacious reptiles which were to succeed them, and the fossil form *Ophiderpeton* suggests that the *Ophiomorpha* may be the last remnants of a race which preceded and represented the subsequently developed serpents. This, however, is but a conjecture which future discoverers will probably ere long establish or refute.

The name *Labyrinthodonta* was bestowed upon the great fossil group on account of the beautiful and singularly complex structure of the teeth of some members of the order. These teeth are conical, and exhibit slight vertical grooves on their surface. A horizontal

[1] Existing Ganoids are the sturgeon, bony pike (Lepidosteus), mud fish (Lepidosiren), and others as noticed earlier.

section shows that these surface-grooves are the external indications of deep indentations of the substance of the tooth. All these indentations converge towards the centre of the tooth, but not in straight lines, each indentation being elaborately inflected. Radiating

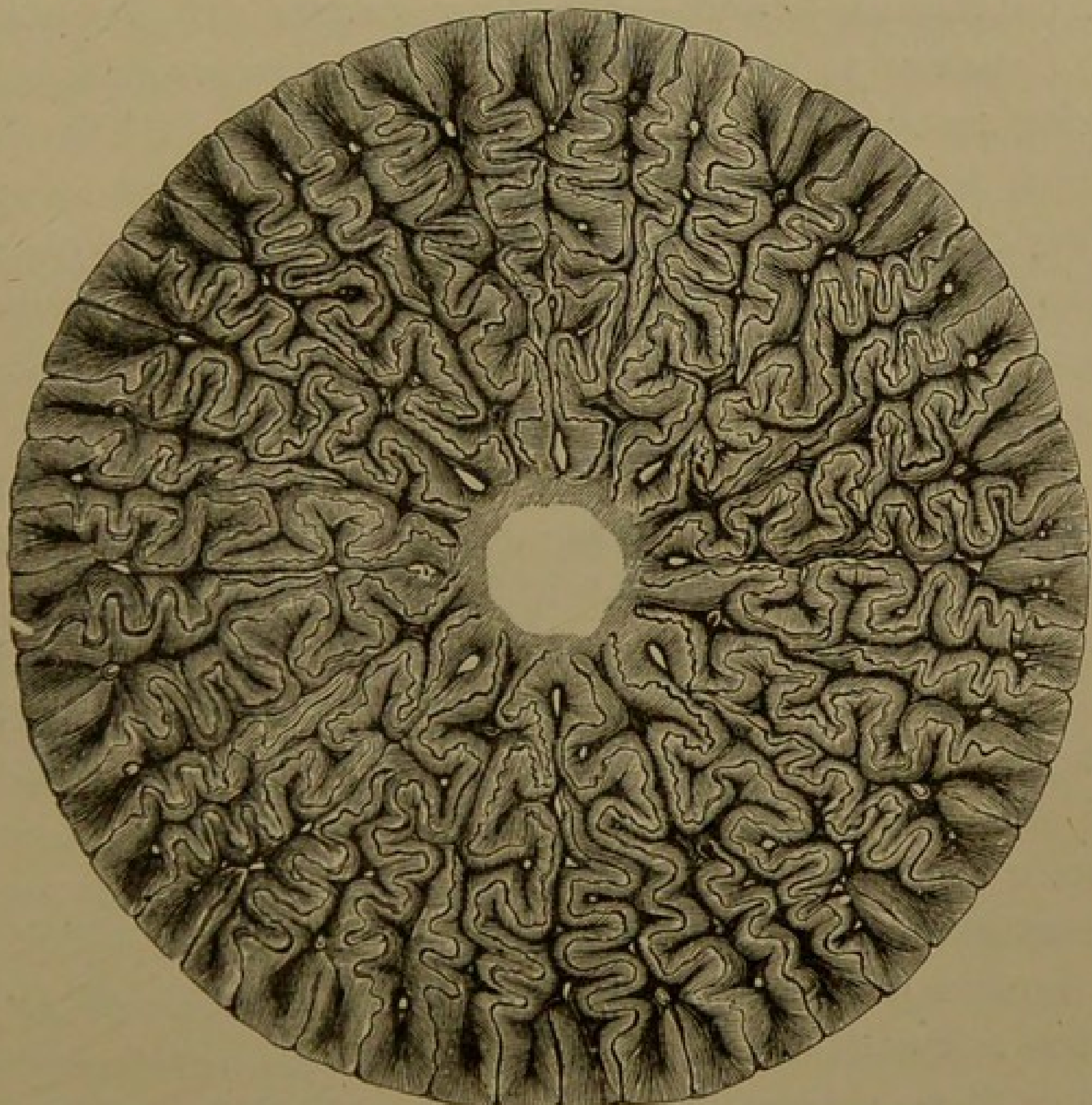

FIG. 23.—Much enlarged horizontal section of the tooth of a Labyrinthodont.

from the centre of the tooth we find a corresponding number of processes of the central pulp cavity—the radiating process undulating like the converging folds.

A similar structure of tooth is found in some Ganoid fishes, and an incipient stage (as it were) of the same condition existed in the Ichthyosaurus.

We have now reviewed the closest as well as the more remote allies of our Frog, and have seen how the Frog is a species of a group (*Anoura*) which is one of three existing and widely diverging orders, supplemented by an extinct ordinal group of the carboniferous period—the four orders (1. *Anoura*, 2. *Urodela*, 3. *Ophiomorpha*, and 4. *Labyrinthodonta*,) being embraced in a higher unity termed a "Class," which is the Frog's *class*, as "Anoura" is his *order*. This class is with propriety spoken of as the *Frog's class*, since the Frog is the species from which its scientific derivation BATRACHIA is derived. This class may now be considered as a whole.

The Batrachians (of all three existing orders) are in the main aquatic animals, inasmuch as the greater number, even when adult, frequent, at least at intervals, ponds and streams, or delight in humid localities. Water also is necessary for the larval stages of almost all; and absolutely all, at one period of life, possess gills, while some (as we have seen) retain gills during their whole existence, and are permanently and constantly inhabitants of water.

The extinct forms (*Labyrinthodonta*) were, no doubt, also aquatic, as, besides their general relation to other Batrachians, traces or indications of the hard parts which supported the branchiæ of some Labyrinthodonts appear to have been actually found.

It is somewhat singular that, in spite of this predominating aquatic habit, all Batrachians, both living and fossil, appear to inhabit, and to have inhabited, fresh-water only. No Batrachian of any period is yet known to have been marine. This is the more remarkable since the most nearly állied class, that of fishes, is much more rich in salt-water than in fresh-water forms; while even existing *Reptilia* have (in the true sea-snakes and in chelonians) representatives which inhabit the open ocean, while in the secondary geological period marine reptiles (*Ichthyosauri* and *Plesiosauri*) abounded.

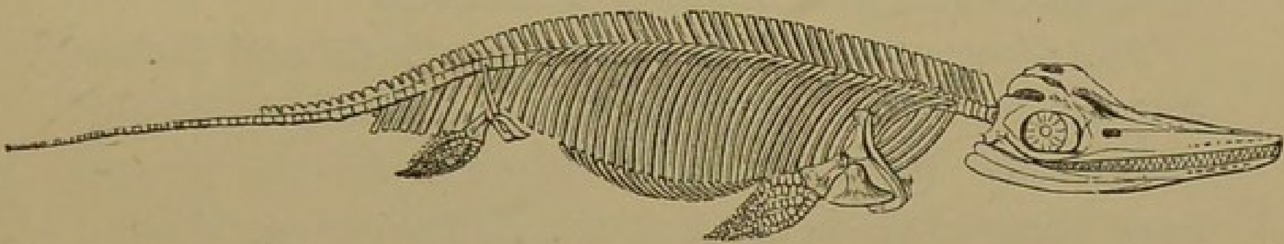

FIG. 24.—Skeleton of the Ichthyosaurus.

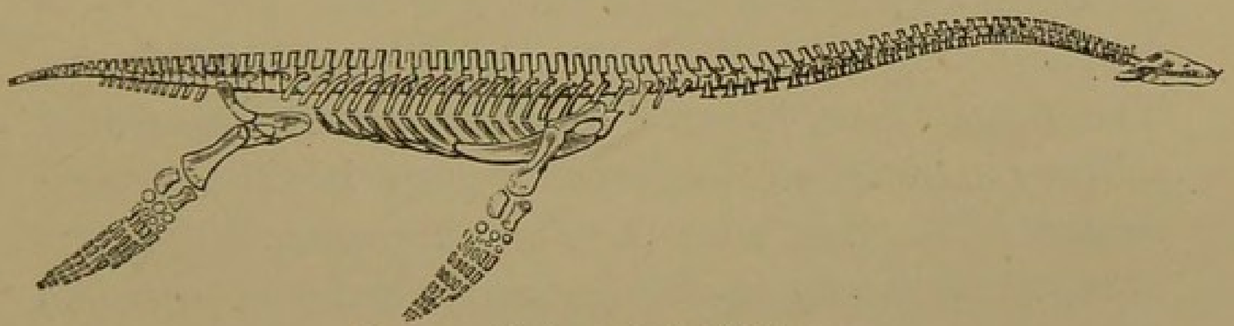

FIG. 25—Skeleton of the Plesiosaurus.

Indeed, of all classes of vertebrate animals, this aquatic class (*Batrachia*) has the least to do with the ocean, for many birds, and a still greater number of Mammals (*e.g.* the whales and porpoises), are constant inhabitants of salt water. All the adult Batrachians feed on animal substances, generally small worms, insects, or slugs and animals allied to slugs. The larger Frogs and Toads will, however, as has been said, devour vertebrate animals, such as mice and small reptiles and birds. The existing large, tailed Batrachians devour fishes. The extinct tailed Batrachians, in their adult condition, were also undoubtedly animal feeders, but they may, in their young state, have been vegetarians. At any rate the tadpoles of the existing *Urodela* will eat vegetable matter, and indeed probably sustain themselves mainly upon it.

In cold latitudes the Batrachia, like the Reptilia, go into the winter sleep called *hibernation*, as also do the hedgehogs and bats amongst Mammals.

The Frogs and Toads sometimes hide and shelter themselves by creeping into out-of-the-way holes and corners, but more generally they (as also the Newts) bury themselves in mud at the bottom of ponds and streams. In hot latitudes, some forms pass the dry season in a similar state of lethargic inactivity.

Many beasts, birds and fishes, range in flocks. The Batrachians, however, usually wander about in a solitary manner, and only congregate in the breeding season. It is then that their vocal powers find utterance, though only in the Anourous order; the tailed Batrachians never make more than a very feeble sound.

As regards the geographical distribution of the whole class, the northern hemisphere, and especially the American portion of it, is the more richly furnished. Africa, India, and Australia are the most poorly supplied on the whole, because, though possessing very many kinds of frogs and toads, the whole Eft order is unknown in those regions.

Our question "What is a Frog?" has now been somewhat further answered; but it cannot be completely so until the organization of the animal has been more fully surveyed, and not only the relation of the frog to other Batrachians thus more clearly seen, but also the relations and affinities borne by the several orders of Batrachians and by the whole class to the other orders or other classes of the Vertebrate sub-kingdom.

Accordingly, we have now to make an acquaintance with more than those obvious and external characters which are found in the Frog, and to penetrate into its inner anatomy, surveying successively its bony frame-work and the various parts and organs which subserve the several actions necessary to its continued existence.

At the same time the more noteworthy resemblances presented by the Frog to other creatures will be pointed out. Thus we shall become acquainted with the relations existing first between the Frog and other members of its order; secondly, between the members of its order (*Anoura*) and its class fellows—*i.e.* other Batrachians; thirdly, we shall comprehend the degree of relationship existing between the Batrachia and the other classes of the Vertebrate sub-kingdom; and fourthly, we shall come to recognise certain singular resemblances which exist between the various groups of Batrachians (the Frog's order of course forming one), and some of the orders into which other vertebrate classes—especially the class of Reptiles—have been divided.

The skeleton of the Frog, both external and internal, naturally comes first as the support and foundation of the other structures. The internal skeleton (or *endo-skeleton*) will include the bones of the head, *i.e.* the skull, back-bone (already referred to), and the bones of the limbs. The external skeleton (*exo-skeleton*) will consist of the skin only.

CHAPTER VI.

THE SKELETON OF THE FROG.

It may cause surprise to speak of the skin of the common Frog as part of its skeleton, consisting as the skin does of small membranous structures only.

The term "skeleton," however, should properly include all the membranous and gristly, as well as the bony structures.[1] Moreover, more or less of the skin may attain to so solid a condition as to justify its comprehension under the name "skeleton," even in the popular signification of that term.

The skin of Vertebrate animals consists of two layers: an outer layer (the epidermis or *ecteron*), and an inner layer (the dermis or *enderon*). The *epidermis*, and any projections or processes developed from it when they take on a dense or hardened structure, become *horny*. Of such horny nature are hairs, feathers, nails, and scales; they are more or less *epidermal* appendages. The *dermis* when hardened becomes *bony*, and of such nature are the bony skin-plates or "scutes" and teeth. They are *dermal*

[1] See "Lessons in Elementary Anatomy," Lesson II., p. 22.

appendages. Now both layers of the skin of the common Frog are entirely soft and utterly destitute

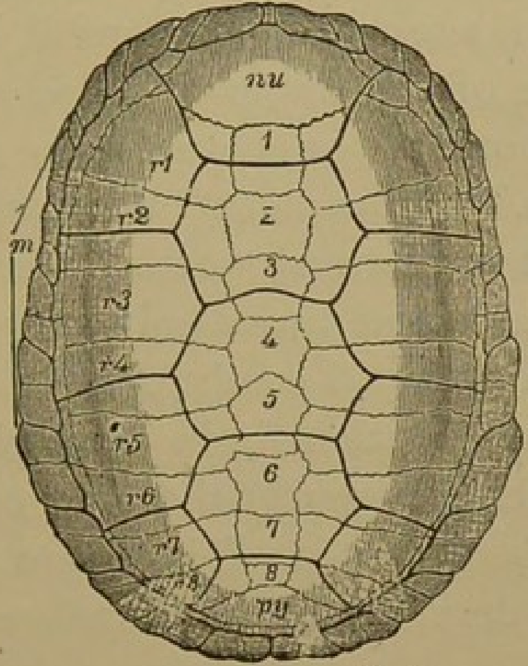

FIG. 26.—Dorsal surface of the Carapace of a Fresh-water Tortoise (Emys). 1—8, expanded neutral spines; r^1—r^8, expanded ribs; *nu*, first median (or nuchal) plate; *py*, last median (or pygal) plate; *m*, marginal scutes. The dark lines indicate the limits of the plates of the horny epidermal tortoise-shell; the thin sutures indicate the lines at the junction of the bony scutes.

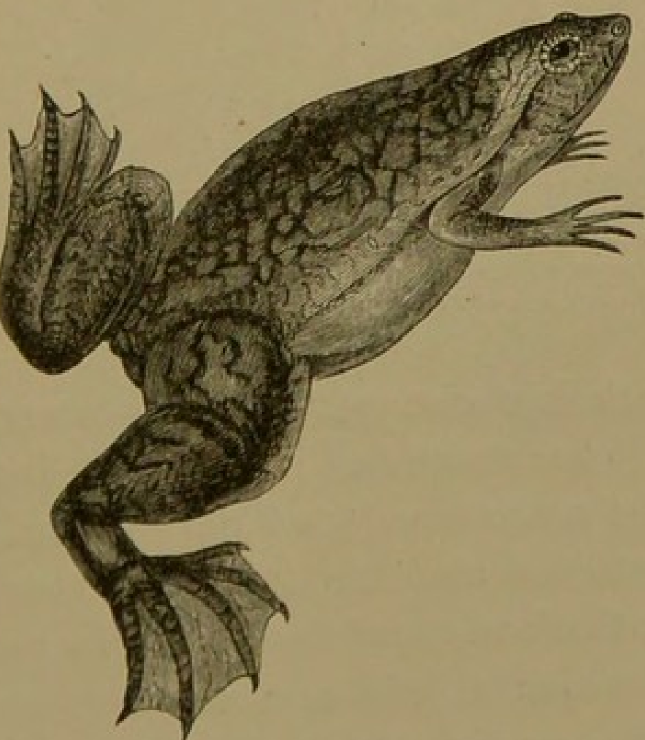

FIG. 27.—*Dactylethra capensis.*

of any of these appendages. Allied forms, however, present us with examples of some interesting epidermal conditions. Thus in old male Toads, in *Dactylethra* and in one of the Japanese efts, the epidermis of some of the finger-tips becomes hardened and horny, in other words we begin to meet with incipient "nails." "Incipient" because, in ascending from the lowest vertebrates, "nails" are first met with in the Frog's class, and these only very rarely and in an imperfectly developed condition.

As has been mentioned, in two kinds of Frog (*Ceratophrys* and *Ephippifer*) the skin of the back is furnished with bony plates. These are found in the deeper layer or dermis, and are therefore "scutes."

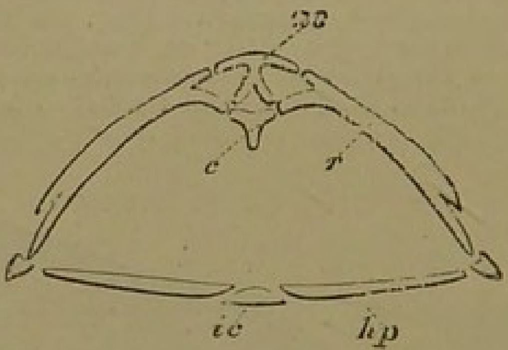

FIG. 28.—Diagram of a vertical section of both Carapace and Plastron of a Tortoise, made transversely to the long axis of the skeleton. *c*, vertebral centrum: *ns*, neural spine which expands above into a median dorsal scute; *r*, rib which forms one mass with a lateral scute and terminates at a marginal plate; *ic*, interclavicular scute; *hp*, hyo-sternal scute.

The remarkable circumstance, however, is that we have here a lower stage (as it were an *incipient* condition) of that more developed dermal skeleton which exists in tortoises and turtles. In most of these reptiles both the back and the belly are protected by bony plates which adjoin one another, and together form a solid box in which the body is enclosed.

Moreover the bony plates of tortoises and turtles are invested by large horny epidermal scales ("tortoise-shell") which scales do not agree in either size or number with the bony plates on which they are superimposed (fig. 26).

Again, the middle series of bony plates of the back are continuous with the subjacent joints of the back-bones, and the lateral series of dorsal plates are continuous with the ribs beneath them (fig. 28.)

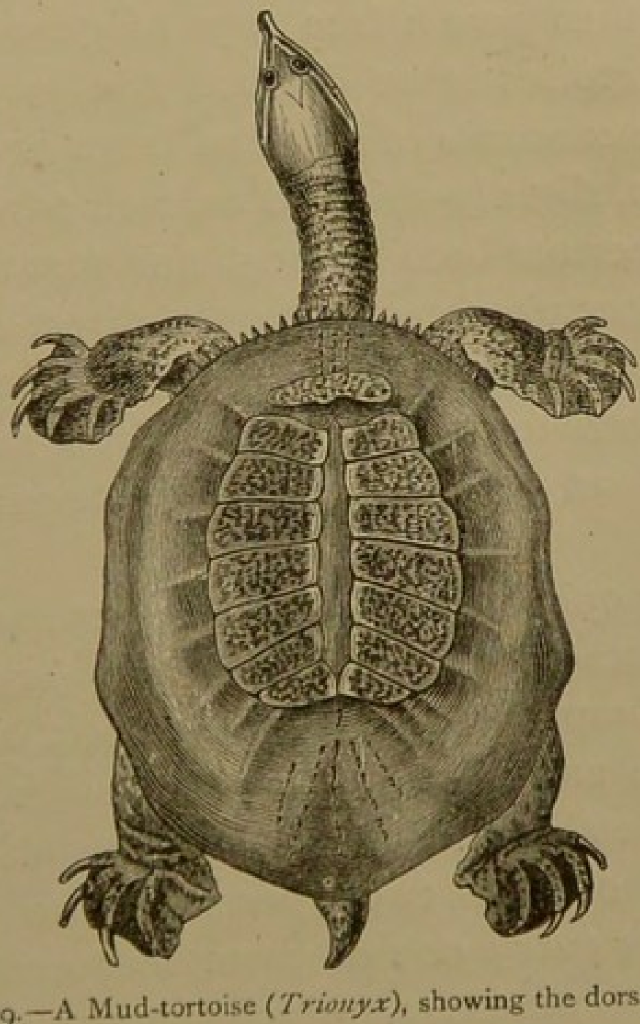

FIG. 29.—A Mud-tortoise (*Trionyx*), showing the dorsal plates.

There are certain Chelonians, however—"mud-tortoises"—(of the genus *Trionyx*), which have the dorsal plates much less developed and not connected with the ventral plates save by means of soft structures. In these latter Chelonians then we have in reptiles an interesting approximation to the condition we have seen to exist in those exceptional Anourans, *Ceratophrys* and *Ephippifer*. Moreover this resemblance is still further increased by the fact that in *Trionyx* the bony plates are not covered with any tortoise-shell, but are merely invested by soft skin as in the genera of dorsally-shielded Batrachians.

Have we then here a true sign of genetic affinity? Are these tortoises to be deemed the more specially modified, descendants of shielded frogs or of some, as yet unknown, slightly-shielded animals which were the common ancestors both of frogs and tortoises?

Certainly tortoises cannot be the direct descendants of frogs, they agree with all reptiles in characters which are both too numerous and too important to allow such an opinion to be entertained for a moment.

The other opinion is hardly less untenable; for if all the multitudinous species of frogs (together with a number of reptilian forms more closely allied to the tortoise than any frogs are) descended from slightly shielded animals, how comes it that all frogs and toads, save one or two species in no other way peculiar, have every one of them lost every trace of such shielded structure, which nevertheless cannot easily be conceived to have been in any way *prejudicial* to their existence and survival?

On the other hand, it cannot but strike us with surprise that structures so similar—extending even to the continuity of the dorsal plates with the subjacent joints of the backbone—should have arisen twice in nature spontaneously. Here we seem to have a remarkable example of the independent origin of closely similar structures; and if so, what caution is not necessary before concluding that *any* given similarity of structure are undoubted marks of genetic affinity!

The skin of the frog is also interesting from a physiological point of view. Our own skin is by no means popularly credited with the great importance really due to it. "Only the skin!" is an exclamation not unfrequently heard, and wonder is very often felt when death supervenes after a burn which has injured but a comparatively small surface of the body. Yet our skin is really one of our most important organs, and is able to supplement, and to a very slight extent even to replace, the respective actions of the kidneys, the liver, and the lungs.[1]

In the frog we have this cutaneous activity developed in a much higher degree. Not only does its *perspiratory* action take place to such an extreme degree that a frog tied where it cannot escape the rays of a summer's sun speedily dies—nay, more, is soon perfectly dried up—but its *respiratory* action is both constant and important. This has been experimentally demonstrated by the detection of the carbonic acid given out in water by a frog over the head of which a bladder had been so tightly tied as to prevent the possibility of the escape of any exhalation from the lungs. The fact of cutaneous respiration

[1] See "Elementary Physiology," Lesson V., § 19.

has also been proved by the experiment of confining frogs in cages under water for more than two months and a half, and by the cutting out of the lungs, the creature continuing to live without them for forty days. Indeed it is now certain that the skin is so important an agent in the frog's breathing that the lungs do not suffice for the maintenance of life without its aid.

It is no less true that in Batrachians which breathe by means of permanent gills—as, *e.g.* the Axolotl—

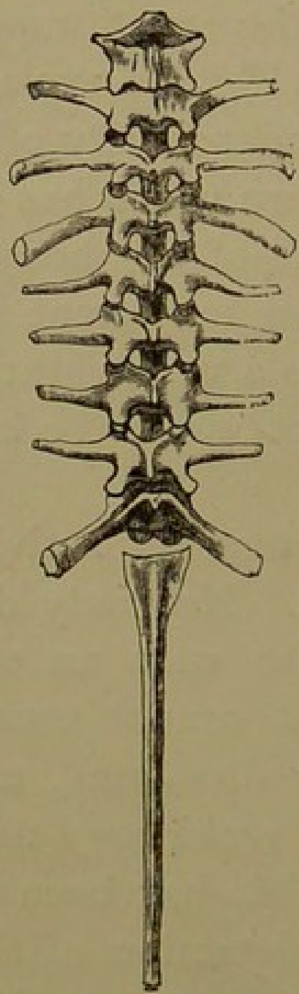

FIG. 30.—Backbone of the Frog (dorsal aspect).

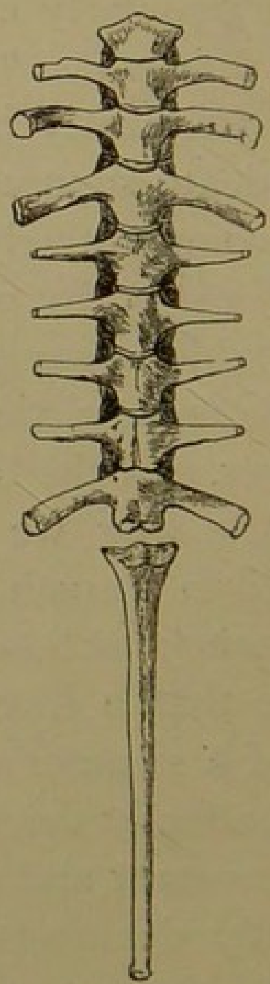

FIG. 31.—Backbone of the Frog (ventral aspect).

such gills are not necessary to life, as the late M. Aug. Duméril and Dr. Günther have established by cutting them away without inducing any apparent injurious effects. In the whole class of Batrachians skin respiration seems, then, to be of very great importance.

The *internal* skeleton (or the skeleton commonly so called) of the frog presents some points of considerable interest, especially as exhibiting its intermediate position between fishes on the one hand, and higher vertebrates on the other. First, as regards the *backbone*, it may be remembered that it is made up of distinct bony joints (or *vertebræ*), in which it agrees with all animals above fishes and with bony fishes; its hinder termination, however, is essentially fish-like.

FIG. 32.—Coccyx of Frog, lateral view, a black line indicates the course of the sciatic nerve.

It is fish-like because the terminal piece, as it is called, or "*coccyx*" (unlike the coccyx in man or in birds) is not composed of rudimentary vertebræ which subsequently blend and anchylose together, but is formed by the ossification continuously of the membrane investing (or *sheath* of) the hindermost part of that primitive continuous rod, or notochord,[1] which, as has been said, precedes, in all vertebrate animals, the development of the backbone, making its appearance beneath the primitive groove.

The vertebræ are shaped like rings, and enclose within their circuit the spinal marrow upon which, as it were, these rings are strung. From the side of each

[1] From Νῶτος, back, and Χορδή, chord.

ring (except at the two ends of the backbone) there juts out a bony prominence called a "transverse process," and to a certain number of these a bony "rib" is in most vertebrate animals attached (though there are none in the frog), often extending round to join the breast-bone in front, and being capable of more or less motion, so as (by their simultaneous movement) to be able to enlarge or to contract the cavity of the chest, which they thus enclose and protect.

That part of each vertebra which is placed next the body cavity is generally the thickest part, and is called the "body," or "centrum." The series of

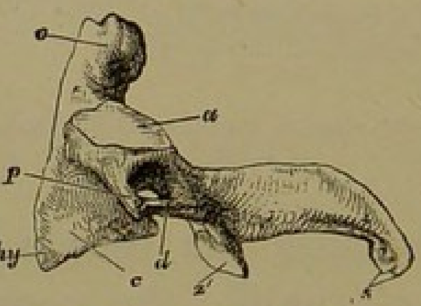

FIG. 33.—The Axis Vertebra of Man. *c*, centrum : *s*, neural spine ; *d*, tubercular process ; *p*, capitular process ; *a*, anterior articular surface for atlas ; *z'*, post-zygapophysis ; *o*, odontoid process ; *hy*, median vertical ridge beneath centrum.

bodies (or centra) occupy the position which was at first filled by the primitive notochord, the rest of the vertebral rings having been formed in the sides and roof of the canal formed by the upgrowth and union of the two sides of the primitive groove of the embryo.

The Frog order is distinguished amongst vertebrates as that which has the absolutely smallest number of joints in the backbone. In the frog there are but nine in the front of the coccyx. In the Pipa toad there are but seven, the eighth vertebra (to the transverse processes of which the haunch bones are attached) having become solidly joined in one bone with the coccyx.

In all higher vertebrates, *i.e.* in all beasts, birds, and reptiles, the head is supported on an especially ring-like vertebra which—because it so supports—is called the *atlas,* and this (in almost all) can turn upon a peculiar vertebra termed (from this circumstance)

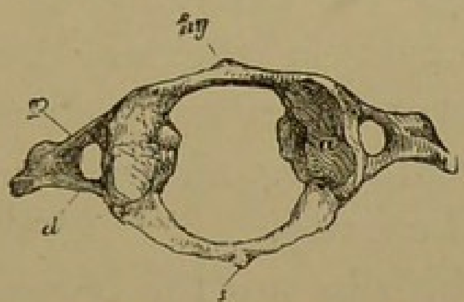

FIG. 34.—The Atlas Vertebra of Man. *s*, rudiment of neural spine; *d*. tubercular process; *p*, capitular process; *a*, articular surface for skull; *hy*, plate of bone holding the place of a cranium, and articulating with the odontoid process of the axis vertebra.

the *axis,* and provided with a toothlike (*odontoid*)[1] process, round which, as round a pivot, the "atlas" works. Nothing of the kind exists in any fish.

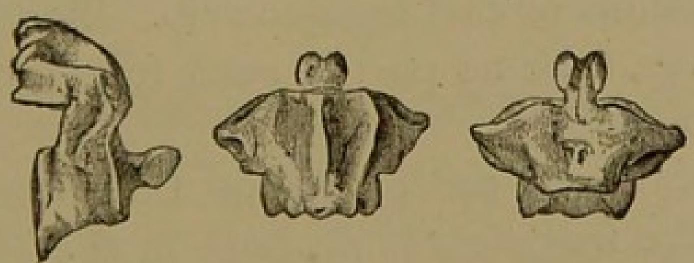

FIG. 35.—Lateral, Dorsal, and Ventral view of first Vertebra of *Amphiuma*.

In the frog (and in all its class) we find but a single vertebra representing these two, but in some allied forms, *e.g.* in *Amphiuma,* this vertebra develops a

[1] From ὀδούς, a tooth, and εἶδος, form.

median process, reminding us of the odontoid process of the axis.

The frog, as has been said, has no ribs, in spite of the long "transverse processes" which project out on each side of the backbone. Ribs are not necessary to it, for it could apply them to none of the purposes to which ribs are ever applied.

In all beasts ribs aid importantly in respiration, serving by their motions alternately to inflate or empty the lungs by enlarging or contracting the cavity of the chest in the way before mentioned. The frog, however, breathes exclusively, as regards the lungs, by *swallowing* air by a mechanism which will be described shortly.

In serpents the ribs are the organs of locomotion, as also in the Flying Dragon before referred to; but in frogs locomotion is effected exclusively by the limbs. In the very aberrant species, *Pipa* and *Dactylethra*, there are on each side of the anterior parts of the body two enormously long transverse processes, each process bearing at its extremity a short flattened, straight osseous or cartilaginous rib. These little ribs can, however, take no part in such functions as those just referred to.

Ribs, moreover, are found in the other existing orders of the frog's class, *i e.* both in the *Urodela* and *Ophiomorpha*. In none, however, do they join a breast-bone, or sternum, another character in which *Batrachians* agree with fishes, though they differ from fishes in that they have a sternum at all. In ascending from fishes through the Vertebrate sub-kingdom, a sternum first appears in the class *Batrachia*.

In a certain North African Salamander named *Pleurodeles* the ribs are not only elongated, but their apices, if they do not actually perforate the skin, are so prominent as to seem to do so, when the finger is drawn from behind forwards along the side of the animal's body.

The several joints of the backbone are connected together by surfaces which are not the same on both the anterior and posterior sides of the centrum, or body, of the same vertebra. Each of the first seven vertebræ is furnished with a round prominence, or head, on the hinder side of its centrum, and each of the precoccygeal vertebræ, except the first and last, has the anterior surface of its centrum excavated as a cup for the reception of the ball of the hinder surface of the vertebra next in front. The first vertebra has in front two concavities, side by side, to articulate with the skull. The eighth vertebra has a concavity at each end of its "body." The ninth vertebra has a body provided with a single convexity in front and a double convexity behind, to articulate with the concavities placed side by side on the front end of the coccyx.

These arrangements are not constant in the frog's order, still less in its class. In *Bombinater* and *Pipa* the vertebræ are concave behind each centrum, instead of in front: and the same is the case in *Salamandra.* In many tailed Batrachians the vertebræ are biconcave, as *e.g.* in *Spelerpes*, *Amphiuma*, *Proteus*, and *Siren.*

The biconcave shape is an approximation towards the condition which is almost universal in bony fishes, though not quite universal, since the bony pike (*Lepidosteus*) has a ball at one end of each vertebra and a cup at the other. Moreover, even in some reptiles (*e.g.* the lizards called *Geekoes*) the vertebræ are biconcave, and the same was the case with the majority of those species of crocodiles the remains of which are found in strata older than the chalk, and even in existing crocodiles the first vertebra of the tail is biconcave.

Vertebræ with a cavity in front of the centrum and a ball behind it are found in the crocodiles now living as well as in the frog, while vertebræ with a ball in front and a concavity behind are found even amongst beasts as in the joints of the neck of Ruminants, *e.g.* the sheep. Thus though the vertebræ of the frog's class exhibit no very decided signs of affinity, they show more resemblance to those of fishes than to those of any other non-batrachian class.

The transverse processes of the ninth or last vertebra in front of the coccyx, articulate with the haunch bones, but are not very remarkable in shape. In some frogs and toads the transverse processes of this vertebra become enormously expanded, and the expanded or non-expanded condition of this part is

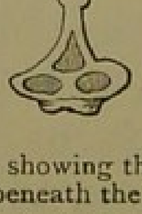

FIG. 36.—Anterior aspect of Coccyx, showing the double articular concavities placed side by side beneath the neural arch.

a character made use of in zoological classification. The coccyx is made up mainly, as has been said, of a continuous ossification of the sheath of the noto-chord, and never consists of distinct vertebra. Nevertheless, the small bony arches which are at first distinct coalesce with it. These arches are called "neural" because they arch over the hinder part of the spinal marrow. The great nerve of the leg (the sciatic nerve) proceeds outwards on each side through a foramen situated at the anterior end of the coccyx from the spinal marrow—the spinal marrow being that structure which gives origin to the great mass of the nerves pervading the entire frame (fig. 32).

The skull of the frog presents numerous points of interest, but only four of these can be here referred to, as other matters demand our attention.

The first of these four relates to its mode of articulation with the vertebral column. As has been said, the first vertebra presents a pair of concavities to the skull. The skull develops from its hinder (or occipital) region a corresponding pair of articular convexities or "condyles." Now in this matter the frog differs from both birds and reptiles, every member of those classes possessing a single median (occipital) condyle for articulation with the vertebral column.

Yet every member of the frog class, not only every toad and newt, but also every species of the Ophiomorpha, and even every one of the long extinct Labyrinthodons (with the doubtful exception of the probably immature and larval *Archegosaurus*) has a similar pair of occipital condyles. The interesting matter is that man and all beasts have also two occipital condyles. Is this then a mark of affinity, and can we, as it were, reach beasts by a short cut through Batrachians, leaving all the reptiles and birds on one side, as a special outstanding and diverging developement?

We shall presently see that other yet more striking facts may be brought forward in support of the latter view. Nevertheless it must be remembered that there are fishes, though very few and exceptional, which also possess a pair of occipital condyles, and that in one respect most fishes are more like mammals than are any Batrachians, since they, like mammals, have a well-ossified median bone at the base of the skull in the occipital region, a structure which all Batrachians, without a single exception, are destitute of.

The second point of interest concerns the lower part, or base, of the skull, which exhibits a striking agreement with the same part as developed in bony fishes.

This agreement consists in the fact that the middle of the floor of the skull is not formed as in all beasts, birds, and reptiles, by a deposition of bony substance in pre-existing gristle (ossification of cartilage), to which the name *Basi-sphenoid* is applied, but, as in bony fishes, by a great bone called *Parasphenoid*, which shoots forwards and also extends backwards to the hinder end of the skull floor, but is formed by the decomposition of bony substance in pre-existing membrane.

Although this great membrane bone is constant in Batrachians and bony fishes, and is represented, if at all, only by minute rudiments in higher vertebrates; nevertheless in serpents we once more meet with a far-reaching and well-developed parasphenoid.

Yet it can hardly be conceived that serpents have carried off from Piscine ancestors and carefully

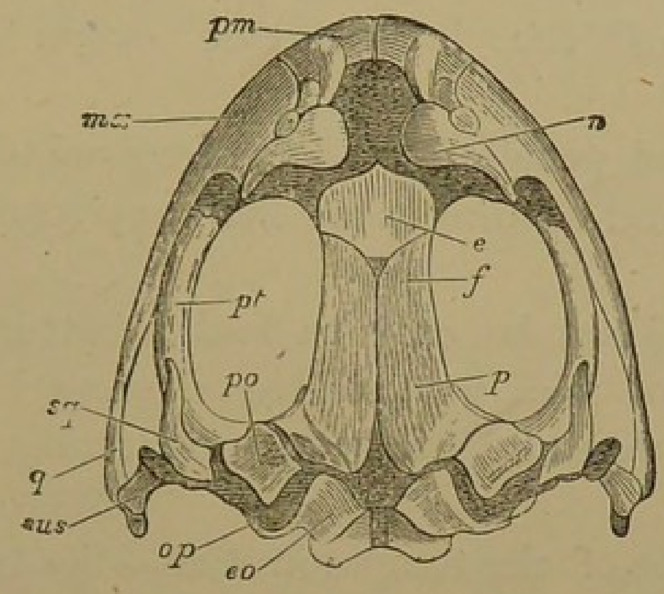

FIG. 37.—Upper Surface of the Skull of a Frog (after Parker). *e*, os en ceinture, or girdle-bone; *eo*, exoccipital; *f*, frontal part of frontoparietal bone; *mx*, maxillary bone; *n*, nasal; *op*, opisthotic; *p*, parietal part of fronto-parietal bone; *pm*, pre-maxilla; *po*, pro-otic; *pt*, pterygoid; *q*, quadrato-jugal; *sq*, squamosal; *sus*, suspensorium of lower jaw.

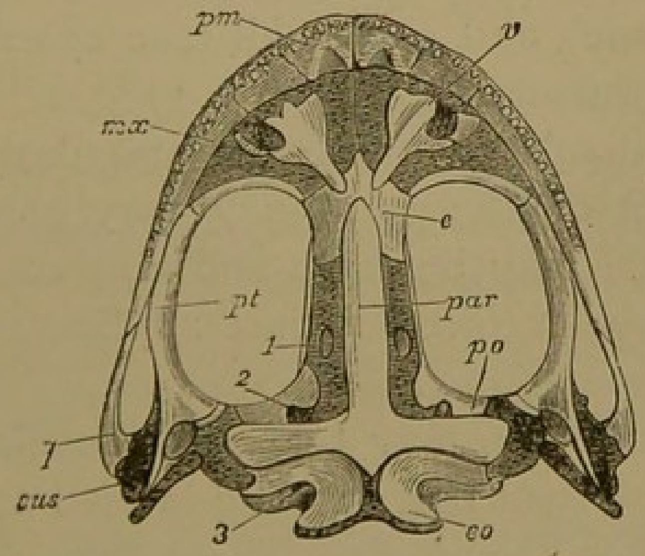

FIG. 38.—Under Surface of the Skull of a Frog (after Parker). *e*, girdle-bone; *eo*, exoccipital; *mx*, maxil'a; *par*, parasphenoid; *pm*, pre-maxilla; *po*. pro-otic; *pt*, pterygoid; *q*, quadrato-jugal; *sus*, suspensorium of lower jaw, the lower end of which represents the quadrate bone; *v*, vomer; 1, optic foramen; 2, foramen ovale; 3, condyloid foramen.

preserved this peculiarity of structure which all their other class fellows have lost. It seems much more probable that this structure has independently appeared through the action of peculiar conditions, and hence that we have here again a remarkable instance of the independent origin of similar structures.

The third peculiarity of the frog's skull consists in the form and conditions of the bony supports of the tongue.

It would not be easy to find a better example of the need of widely extended observations in order duly to understand structures apparently very simple indeed.

The bone of the tongue in man—the *os hyoides*[1]—is a small structure, and one to all appearance of little significance. It is placed at the root of the tongue and above the larynx, and consists of a body with a pair of processes on each side, one large (the posterior or great cornu), and one small (the anterior or lesser cornu, or corniculum).

Even in man's own class (mammalia) the relative development of the parts may vary greatly. Thus the cornicula may be large and may each be represented by two or three distinct applications as in the dog and horse.

The cornua also may take on a development very much greater than that existing in man as is the case in some other Mammals. These facts may prepare us to expect much greater divergences in lower forms; and yet throughout the two great classes of birds and reptiles (as well as beasts)—though varying conditions as to the proportions of the parts present themselves

[1] So named from its resemblance to the Greek letter υ.

—the os hyoides continues essentially the same in structure, and even in the adult frog this bone exhibits nothing but a rather wide "body" with two long and slender "cornicula" and a pair of shorter "cornua."

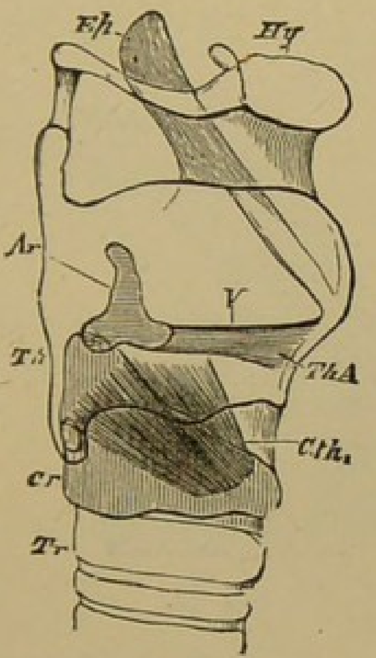

FIG. 39.

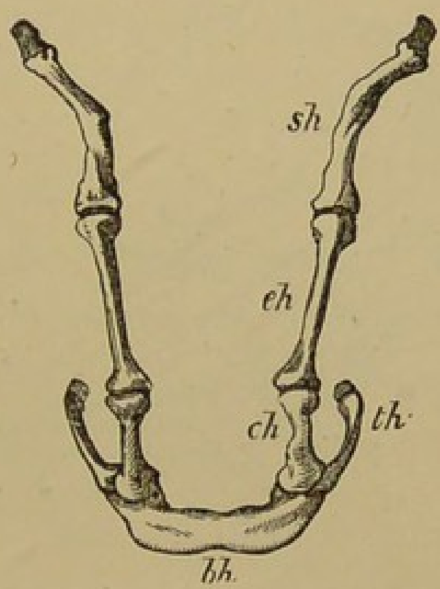

FIG. 40.

FIG. 39.—Diagram of the Larynx of Man, the thyroid cartilage being supposed to be transparent, and allowing the right arytenoid cartilage (*Ar*), vocal ligament (*V*), and thyro-arytenoid muscle (*Th A*), the upper part of the cricoid cartilage (*Cr*), and the attachment of the epiglottis (*Ep*), to be seen. *C th*, the right cricothyroid muscle; *Tr*, the trachea; *Hy*, the body of the hyoid bone. The right lesser cornu appears as a very small process, extending upwards and backwards from the body of the hyoid behind the letters *Hy*, and in front of the Epiglottis. The right, great cornu is shown extending backwards from the body of the Hyoid and terminating beneath the letters *Ep*.

FIG. 40.—Extracranial portion of hyoidean apparatus of Dog, front views *sh*, stylohyal; *eh*, epihyal; *ch*, ceratohyal (these three constitute the "anterior cornu"); *bh*, basihyal, or "body" of hyoid; *th*, thyrohyal, or "posterior cornu." (From Flower's "Osteology.")

Let us now pass for a moment to the other end of the Vertebrate sub-kingdom. We find in fishes a complex framework for the support of the gills, or structures, by which they effect their aquatic respiration. This framework consists of a number of arches (placed in series one behind another) extending on each side of the throat upwards towards the back-bone, and supporting on their outer sides the gills or branchia, on which account they are called the *branchial arches*. In front of these arches and forming as it were the first of the series, is an arch which ascends and becomes connected with the skull.

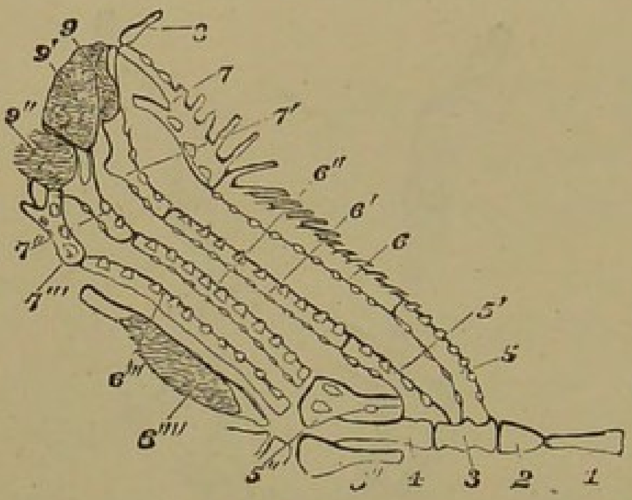

FIG. 41.

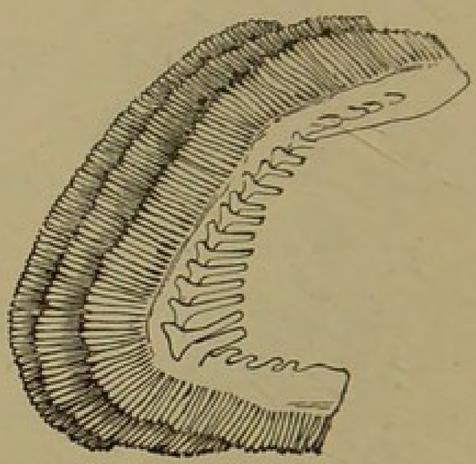

FIG. 42.

FIG. 41.—Skeleton of left series of Branchial Arches of a Perch, seen from above. 1, glosso-hyal; 2, 3, and 4, basi-branchials; 5, hypo-branchials; 6, cerato-branchials; 7, epi-branchials; 8, styliform pharyngo-branchials; 9, pharyngo-branchials; $6''''$, inferior pharyngeal bone; $9'$ and $9''$, superior pharyngeal bones; 5, 6, 7, and 8, first branchial arch; $5'$, $6'$, $7'$, and 9, second branchial arch; $5''$, $6''$, $7''$, and $9'$, third branchial arch; $5''$, $6'''$, and $7'''$, fourth branchial arch; $6''''$, fifth branchial arch.

FIG 42.—First three branchial Arches from the left side of a Perch. On the outer (convex) side of each branchial arch the series of closely-set gill filaments (or leaflets or lamellæ) are seen to be attached. On the inner (concave) side of the first branchial arch are the series of elongated processes (supporting minute denticles) which help to prevent particles of food, or other foreign bodies, passing from the mouth to the gill chamber.

Turning now to those Batrachians which breathe throughout their lives in the manner of fishes, we find a corresponding system of branchial arches. Thus in the Siren we find a series of gill-supporting branchial arches, placed behind another arch which is connected with the skull.

But the frog passes the first part of its life in a fish-like manner, and in the tadpole accordingly we find an apparatus similar to that of the Siren. There are, in fact, on each side of the throat, four branchial arches, placed behind another arch, which is connected with the skull. As development proceeds these *branchial* arches become gradually absorbed and all but disappear. Relics of them, however, exist even in the adult condition, and thus serve to indicate the true nature of parts which otherwise would be little understood.

The central portion of the structure—that from which arches diverge on each side—increases in relative as well as absolute size, and becomes the

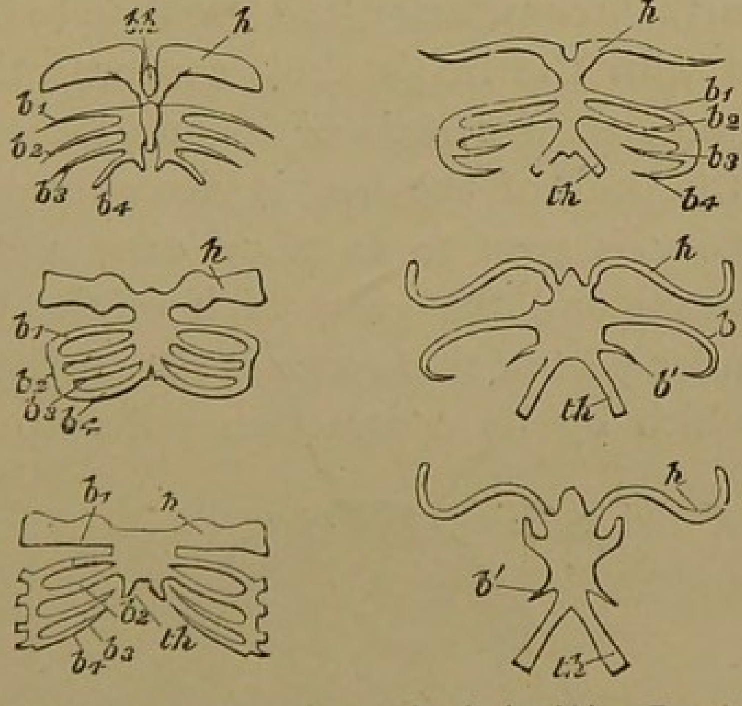

FIG. 43.—Diagram of the changes undergone by the hyoid in a Frog in passing from the Tadpole stage to the adult condition (constructed from Parker's Memoir). Uppermost left-hand figure, the youngest condition; lowest right-hand figure, the adult. *h*, the hyoidean arch, ultimately the corniculum; b^1—b^4, the four branchial arches which become gradually atrophied, the cornua (or thyro-hyal) *th* being their representative in the adult; *b'*, another branchial rudiment; *bh*, the body of the hyoid.

"body" of the *os hyoides*. That arch on each side which is connected with the skull and is placed immediately in front of the branchial arches, continues to be so connected, and becomes one of the two "cornicula," while the rudimentary relics of the branchial arches which persist become what we have seen in the adult as the cornua of the *os hyoides*.

Thus the anatomy of the tongue-bone of the frog, studied in its progressive changes, reveals to us that otherwise unsuspected relations exist in certain parts of the tongue-bone of man. It exhibits to us the cornua of his *os hyoides* as related to those large and complex branchial arches which play so important a part in the fish and form so relatively large a portion of its skeleton.

The fourth circumstance (the last here to be noticed) connected with the frog's skull concerns the relative position and size of certain of its enveloping bones.

When the skull of the frog is viewed from above, a large vacuity is seen to exist on each side, between the brain-case and the great arch of the upper jaw. In the hinder part of this space is situate the temporal muscle, which by its contraction pulls up the lower

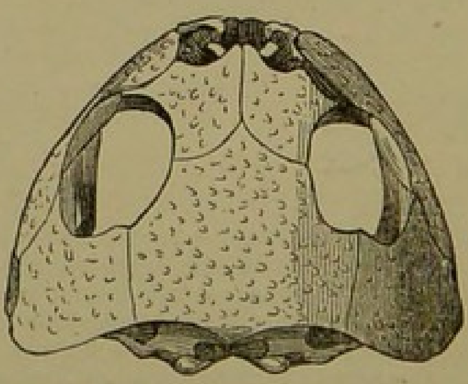

FIG. 44.—Dorsal view of skull of *Pelobates*, showing bony lamellæ behind the orbits.

jaw and closes the mouth ; and the hollow in which this muscle lies is called the temporal fossa.

In a certain frog before noticed, called *Pelobates*, as also in *Calyptocephalus*, a similar view of the skull exhibits no such great vacuity. The reason of such absence is that the temporal fossa in these animals is roofed over and enclosed by the meeting together of bony lamellæ developed from the bones surrounding it, which thus bound the orbit posteriorly, and give to the cranium an altogether false appearance of great capacity.

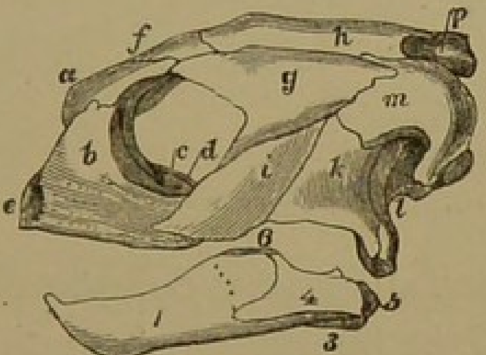

FIG. 45.—Lateral view of skull of Turtle (*Chelonia*), showing bony lamellæ behind the orbit. *a*, naso-præfontal; *b*, maxillary; *c*, palatine; *d*, basi-sphenoid; *e*, præmaxillary; *f*, frontal; *g*, post-orbital; *h*, parietal; *i*, jugal; *k*, quadrato-jugal: *l*, quadratum; *m*, squamosal; *p*, super-occipital; 1, dentary; 3, angular; 4, surangular; 5, articular; 6, coronoid.

This very singular structure is found to exist also in the marine turtles, amongst the Chelonians, and here we have another striking resemblance between the Chelonia and the Anoura, apparently reinforcing the argument for the existence of real affinity derived from the presence of such bony dorsal shields in both those two orders. The importance of this character might seem the more unquestionable, since no other reptiles and no birds or beasts whatever were known to exhibit a similar structure.

Quite recently, however, Prof. Alphonse Milne-Edwards has described a beast from Africa (*Lophiomys*) belonging to the Rodent (rat, rabbit, and squirrel) order, which has a skull, the temporal fossa of which is similarly enclosed by bony plates.

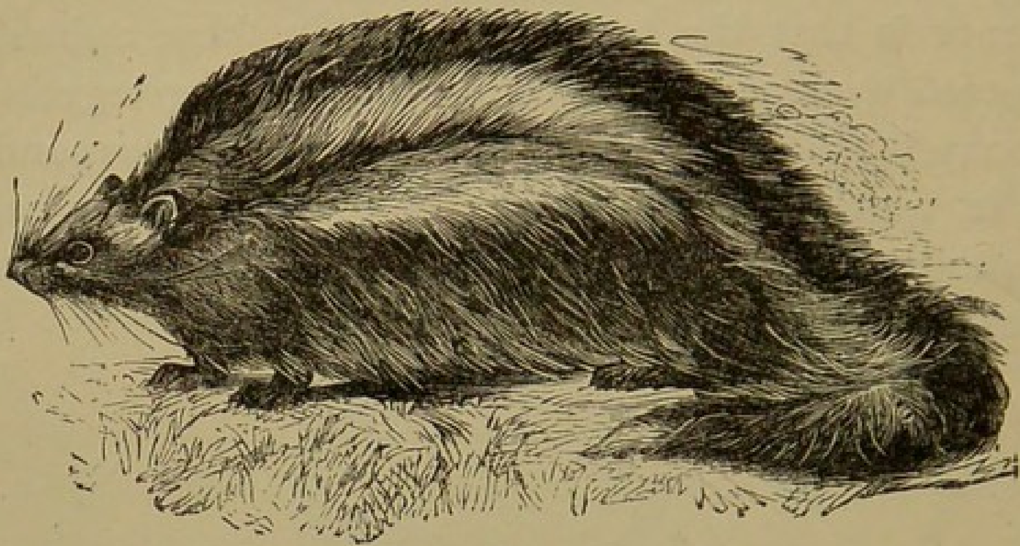

FIG. 46.—External form of *Lophiomys*.

This unexpected discovery completely destroys any weight which might be attached to this character as an evidence of genetic affinity. It does so, because it is inconceivable that this Rodent should have directly descended from a common progenitor of frogs and of Chelonians through a line of ancestors which never lost this cranial shield, though the ancestors of all other beasts, all birds, and all reptiles, except turtles, *did* lose it. It is inconceivable, for if it were true, a variety of the lowest mammals (Marsupials[1] and Monotremes[2]) must have less diverged from the ancient common stock than have the members of the Rodent order, and nevertheless these lowest mammals exhibit no trace whatever of such a cranial shield.

Here then we have an undoubted example of the

[1] *i.e.* Opossums, kangaroos, &c.

[2] The Ornithorhynchus and Echidna.

independent origin of structures, so similar that at first sight their similarity might well have been deemed a conclusive evidence of affinity.

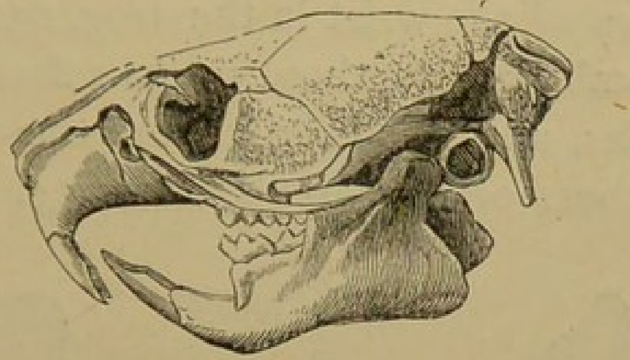

FIG. 47.—Lateral view of skull of *Lophiomys*, showing bony lamellæ behind the orbit.

Here, also, we have a memorable caution against hasty inferences from structural similarities. If this resemblance and that of the dorsal shields are, when taken together, no signs whatever of special genetic affinity—it is difficult to say what structural likenesses are to be deemed unquestionable evidences of a common ancestry.

Passing now to the skeleton of the limbs, we come to a character of great significance, as it is one which serves to distinguish all the limbed species of the frog's class from lower vertebrates. The character is very significant, because all Batrachians, in spite of their numerous and important fish affinities, differ from all fishes, and agree with all higher classes in that they—if they have limbs at all—have them divided into those very typical segments which exist in man; namely, shoulder-bones, arm-bones, wrist-bones, and hand-bones; and into haunch-bones, leg-bones, ankle-bones, and foot-bones respectively. It is difficult, then, to avoid the belief that in the Batrachian class we come upon the first appearance of vertebrate limbs, differentiated in a fashion which thenceforward becomes universal.

The bones of the wrist in the frog, again, present a nearer resemblance to those in man than do those of most reptiles, and this is still more the case in some other members of the frog's class, *e.g.* *Salamandra*

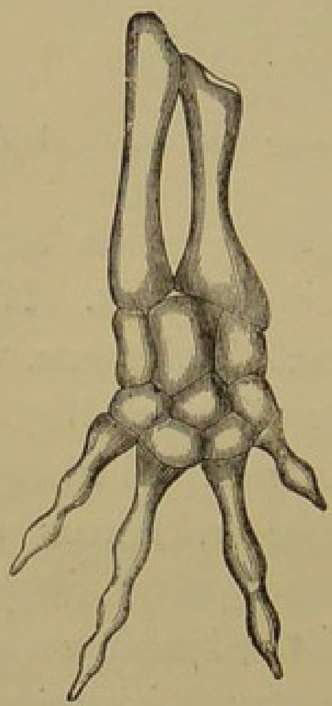

FIG. 48.

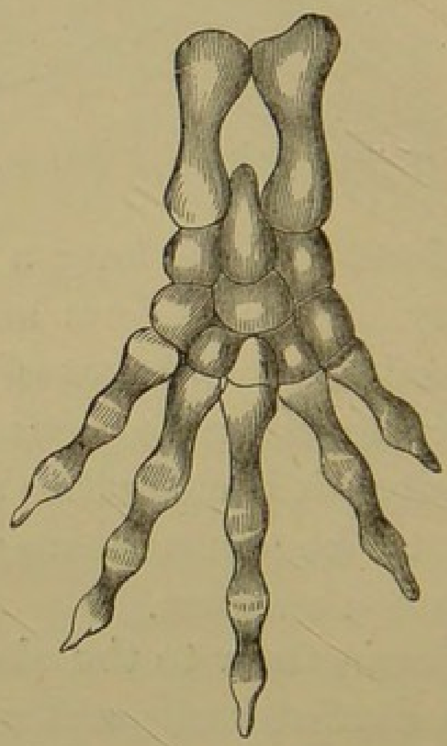

FIG. 49.

FIG. 48.—Skeleton of anterior extremity of an eft.
FIG. 49.—Skeleton of posterior extremity of the same.

and other Efts. Nevertheless, there are certain reptiles, and, strange to say, they are once more Chelonians, which agree in this resemblance—as may be seen in the hand of the tortoise — *Chelydra serpentina.*

The bones of the fingers show, moreover, a greater likeness, in certain respects, to those of beasts than to those of reptiles. No finger has a greater number of joints than three, while, in some lizards, the fourth digit may have as many as five joints.

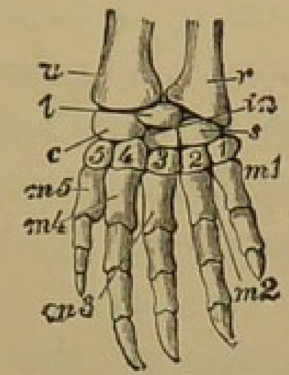

FIG. 50.—Dorsal surface of skeleton of right hand of the Tortoise, *Chelydra* (after Gegenbaur). *c*, cuneiforme; *in*, intermedium (or centrale); *l*, lunare; *m*1—*m*5, metacarpals; *r*, radius; *s*, scaphoides; *u*, ulna; 1—5, the five distal carpals, namely—1, trapezium; 2, trapezoides; 3, magnum; 4 and 5, divided unciforme.

In the frog the wrist-bones (called respectively the magnum and unciforme) which support the third, fourth, and the little fingers, are formed together into a single ossicle. The same condition, however, sometimes occurs even in the orang. On the other hand, the single bone which in man and beasts supports both the "ring" and the "little" fingers, may be represented by two ossicles in the frog's class (as *e.g.* in *Salamandra*) and in some reptiles (as *e.g.* in *Chelydra*).

No member of the frog's class which has an arm at all, bears less than two fingers (as in *Proteus*) upon it. Thus we meet with a number as small as that which is developed amongst beasts in ruminants, but not so small a number as in the horse.

In the rudimentary condition of its thumb the frog participates in a very common defect, since this member is absent in very many forms. It is so even in creatures as highly organised and as like man in bodily structure as monkeys, since both the spidermonkeys of America and certain long-tailed monkeys (*Colobi*) of Africa, are thumbless.

In man, when standing, the weight of the body is transferred to the limbs by a large bony girdle which, from its basin-like shape, is called the *pelvis*. This basin consists of the two haunch-bones which meet together in front, but behind are separated by the lower part of the backbone (called the sacrum), to which the haunch-bones are attached, and which forms the hinder portion of the pelvis. The pelvis has a depression, or "socket," on each side, into which fits the head of one of the thigh-bones. Each "haunch-bone" consists of three parts, which are, in

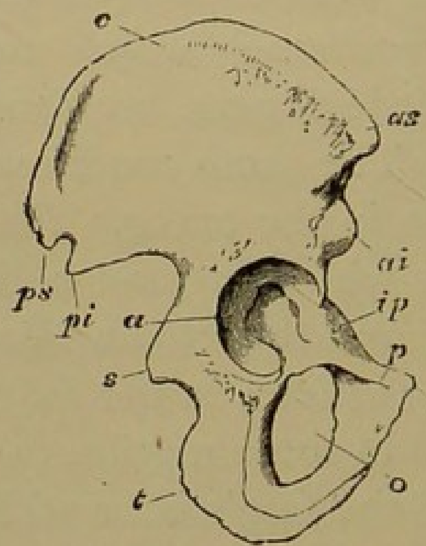

FIG. 51.—Outer side of os innominatum of Man. *a*, acetabulum; *ai*, anterior inferior spinous process of the ilium; *as*, anterior superior spinous process of the ilium; *c*, crest of the ilium: *ip*, ilio-pectineal emineuce; *o*, obturator foramen; *p*, pubis —its horizontal ramus: posterior inferior spinous process; *ps*, posterior superior spinous process; *s*, spine of the ischium; *t*, tuberosity of the ischium.

man, primitively distinct, but afterwards anchylose together, and all three elements (in each haunch-bone) take a share in the formation of the bony thigh-socket or *acetabulum*. These three elements are named—1, *ilium*; 2, *ischium*; and 3, *pubis*. It is the ilium which is adjoined to the sacrum. The pubis, in man, meets its fellow of the opposite side in the middle line in the front of the body. The two ischia (one to each haunch-bone) support man's body when in a sitting posture.

The pelvis of man is often quoted as one of the most peculiar and characteristic parts of his skeleton, and its shape in him *is* very peculiar. Nevertheless the pelvis as it exists in frogs and toads is a far more exceptional structure. It is so in the extraordinary elongation, yet small vertebral attachment, of the haunch-bones (*ilia*), as also in the fact that these bones as well as the other pelvic elements (*ischia* and *pubes*) are all closely applied to each other in the middle line

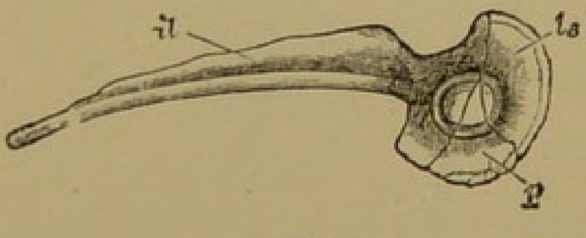

FIG. 52.

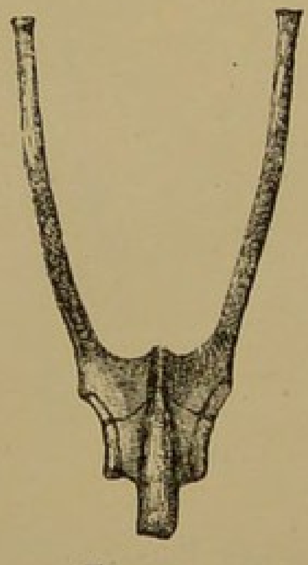

FIG. 53.

FIG. 52.—Right side of Pelvis of Frog. *il*, ilium ; *is*, ischium ; *p*, pubis. The three bones meet at the upper margin of the acetabulum.

FIG. 53.—Dorsal view of pelvis of Frog, showing the narrow ends of the ilia for attachment to the backbone, and also the close approximation of the acetabula.

of the body. Thus these elements form a bony disc, and the two sockets (*acetabula*) destined, respectively, for the heads of the two thigh-bones, come to be closely approximated one against the other. The great elongation and small attachments of the ilia allow the pelvis as a whole to be bent upon the backbone. Thus the hinder part of the body is movable, and forms, as it were, an additional common root segment for the two limbs.

The skeleton of the ankle as developed in the frog's class presents us with some characters, which, more than even those of the wrist, suggest the passage of the line of affinity directly from Batrachians to mammals, leaving both reptiles and birds on one side.

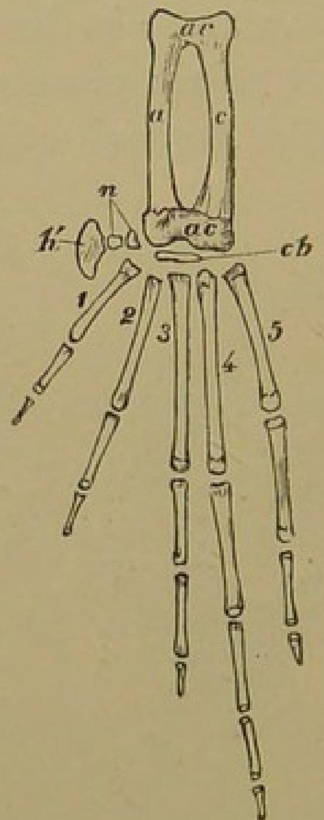

FIG. 54.—Bones of foot of Frog.—*a*, astragalus ; *c*, os calcis ; *ac*, united portions of these bones ; *li*, extra ossicle of inner side of foot ; *cb*, ossicle representing cuboid and other tarsal bones—1, 2, 3, 4, 5—the five metatarsals.

In the first place we meet in the frog with certain extra ossicles in the inner side of the foot, which present the appearance of a broad rudiment of an extra digit on the inner side of the great toe. Now we find a structure very similar in form in animals remote enough from Batrachians, yet rarely do we find such in any intermediate kinds. Thus in certain tree-porcupines the ankle is furnished in like manner —another instance of the independent origin of strikingly similar structures.

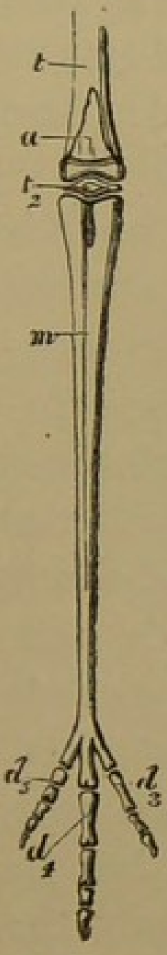

FIG. 55.

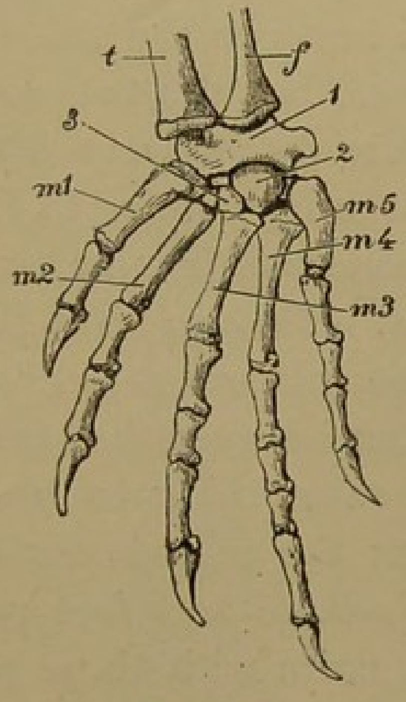

FIG. 56.

FIG. 55.—Right foot of Emeu. *a*, astragalus; d_2—d^4, second, third, and fourth digits; *m*, metatarsals anchylosed together except at their distal ends; *t*, tibia, t_2, distal tarsal element.

FIG. 56.—Left foot of a Monitor Lizard (*Varanus*). *f*, fibula; m^1—m^5, the five metatarsals, m^1 being that of the hallux; *t*, tibia; 1, astragalo-calcaneum; 2, cuboides; 3, ecto-cuneiforme.

There are other matters, however, more important than this. It has been remarked that the wrist shows an amount of resemblance to the same part in beasts which is wanting in most reptiles and in all birds.

The same observation may be repeated with far greater force as regards the ankle.

In all beasts, as in man, the motion of the leg on the foot takes place by means of a joint between the shin-bone of the leg and the small bones of the ankle; and though in some beasts (as in the orang) there is considerable power of motion between the first and the second row of ankle-bones, this is small compared with the mobility of the foot and ankle taken together upon the leg.

In all birds, on the contrary, not only is there no motion between the ankle-bones (as a whole) and the shin-bone, but the two rows of ankle-bones actually anchylose respectively with adjacent parts—the row nearer the leg coming to form one with the shin-bone; the second row coming to form one with the bones of the foot. Thus in birds the motion of the foot on the leg takes place not between the ankle and the shin-bone, but between the two rows of ankle-bones.

The same thing to a less degree takes place in reptiles; the ankle-bones do not indeed *anchylose* with the shin-bone and foot respectively, but they nevertheless unite with those parts so firmly that motion takes place between the bones of the ankle and not between the whole ankle and the leg.

Now in the frog's class, *e.g.* in the order *Urodela*, we meet with a condition which is mammalian rather than reptilian or avian. Motion takes place freely between the leg and the whole tarsus. Moreover, the number and proportions of the ankle-bones themselves far more closely agree with the condition of the same parts exhibited to us by certain beasts than it does with that which is possessed by any bird or by most reptiles.

The frogs and toads, however, differ from the *Urodela* and present us with a peculiar condition of the ankle-bones, in that the two which represent the bones of the first row are so greatly elongated as to give to the limb an additional segment—as it were two "long bones" more.

We should search in vain through every other order of the Batrachian class, through every known group of birds and reptiles, both living and fossil, to find any

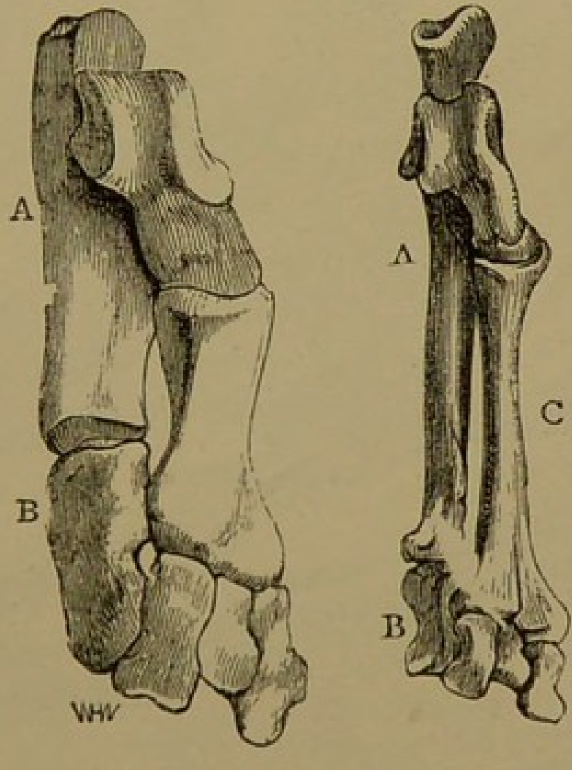

FIG. 57.—Elongated tarsus of Lemuroids. Left-hand figure, tarsus of *Cheirogaleus*; right-hand figure, tarsus of *Tarsius*. *A*, calcaneum *B*. cuboides, *C*, naviculare.

analogous structure. None of the lowest mammals, no marsupial, no rodent, no insectivorous or carnivorous beast, no hoofed mammal, presents us with anything of the kind. Nevertheless, at almost the other end of the series, in the very highest order, that to which man himself belongs, we actually find a similar development.

Amongst the very peculiar beasts which inhabit the island of Madagascar, there are certain small creatures,

FIG. 58.—The Maholi Galago.

" Half-Apes," belonging to the genus *Cheirogaleus*, in which two of the ankle-bones are elongated in a manner similar to that of the frog. The same character is more marked in an African genus of half-apes (*Galago*), and still more so in a third half-ape (*Tarsius*), from the island of Banca. Now it is absolutely impossible to believe that a special genetic affinity connects together by a peculiarly common descent, Half-Apes and Frogs! We are then driven to the conclusion that we have here again a striking similarity of structure in two instances which are quite independent in their origin.

That the power of rapid and prolonged "jumping" does not carry with it as a necessary consequence the elongation of ankle-bones, is demonstrated by the fact that in other animals which, to say the very least, jump no less than do these half-apes—as for example in the kangaroos, jumping shrews, and jerboas—it is not bones of the ankle but bones of the foot proper, which take on an augmentation in length.

CHAPTER VII.

THE MUSCLES OF THE FROG.

WE may now pass to the consideration of some points exhibited by another set of structures—namely, the muscles.

The muscles of an animal constitute its flesh, which as the most ordinary inspection shows us, is composed of different portions of soft fibrous substance, such portions being separated from one another by interposed layers of membrane. Each such portion, so separated, is a muscle, and is attached at its two ends to two parts (bones or what not), which may be adjacent or more or less distant. The fibres which compose it have the remarkable property of contracting under certain conditions, and, when contracted, the whole muscle is shorter and thicker than before, and the two parts to which it is attached become consequently approximated.

Muscles may be large expanded sheets of flesh (as in the abdomen), or long and more or less narrow, as in the limbs.

Muscles are said to be "inserted," or to "take origin from" the parts to which they are attached, and they may be so inserted either by their own muscular fibres or by the intervention of a tough membrane or a dense fibrous cord called a "tendon."

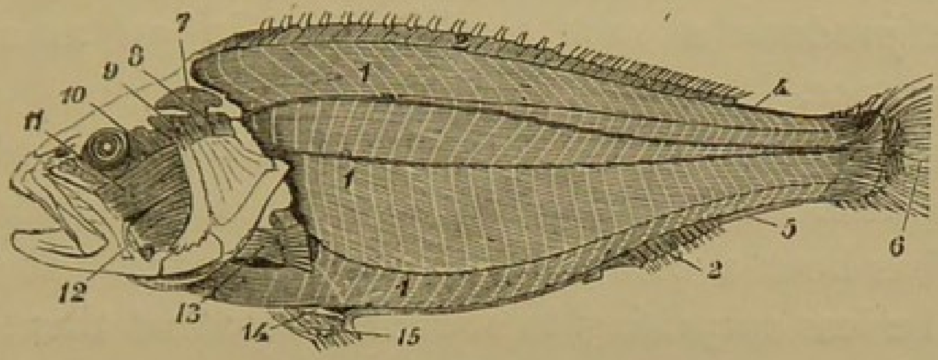

FIG. 59.—Superficial Muscles of the Perch. The fin-rays of all the fins are cut off. 1, great lateral muscle, showing the numerous vertical tendinous intersections slightly but variously inflected; 2, small superficial muscles inserted into the fin-rays of the dorsal and ventral fins; slender longitudinal muscle running (in the interval of the summits of the two great lateral muscles) between the dorsal and caudal fins; 5, similar muscle on the ventral margin, which also appears between the anal and ventral fins; 6, small radiating muscles of the caudal fin; 7, part of the great lateral muscle inserted into the skull; 8 and 9, elevators of the operculum; 10, elevator of the palato-quadrate arch; 11 and 12, muscular mass by which its contraction closes the jaws; 13, superficial muscles of the pectoral fin; 14 and 15, muscles of the ventral fin.

All the motions of an animal are produced by means of the contractions of its muscles pulling the bones, which act as so many levers (of different kinds according to circumstances), and so effecting locomotion.

These muscular contractions are in life produced by the agency of certain of the nerves proceeding from the nervous centres, *i.e.* from the brain and spinal marrow, and which carry an influence outwards to the muscles. Other of the nerves so proceeding convey an influence inwards to the nervous centres from an irritated portion of the body's surface.

The muscles, however, especially in the frog, may, for a time, be made to contract after death by direct irritation of the nerves themselves.

After the skeleton, it is the muscular formation of the body which mainly determines its general form and aspect, though occasionally—and often in the Frog's order—the voluntary inflation of the lungs will alone produce a vast modification in an animal's appearance.

The curious and grotesque resemblance which exists between the figure of the adult frog and that of man has been a common subject of remark. It may then be less surprising to some to learn that there is a great degree of resemblance between the muscles of the Rational and of the Batrachian animals; though the much greater gulf which separates the Batrachian than the Reptilian class from mammals may lead others to anticipate a greater divergence than in fact exists.

The frog, however, in its immature stage of existence, is widely different from the adult in its muscular (or myological) furniture, and this for one obvious reason.

"Muscles" are, as we have shown, *par excellence*, "organs of motion," and the motions of the tadpole are essentially different from those of the frog.

The frog, as all know, progresses on land by jumps, and swims through the water by a series of movements which are in fact aquatic jumps. This action is familiar to many of us, not only from observation but also by imitation (the frog being a swimming-master given us by nature), but it is none the less a mode of swimming which is very exceptional indeed.

The tadpole progresses through the water in a very different manner, namely, by lateral undulations of its tail, which is the usual mode of swimming among vertebrate animals—that made use of by sharks and porpoises, as well as by the overwhelming majority of fishes.

Studying the life-history of this one animal, then, we become acquainted with a process of direct tran-

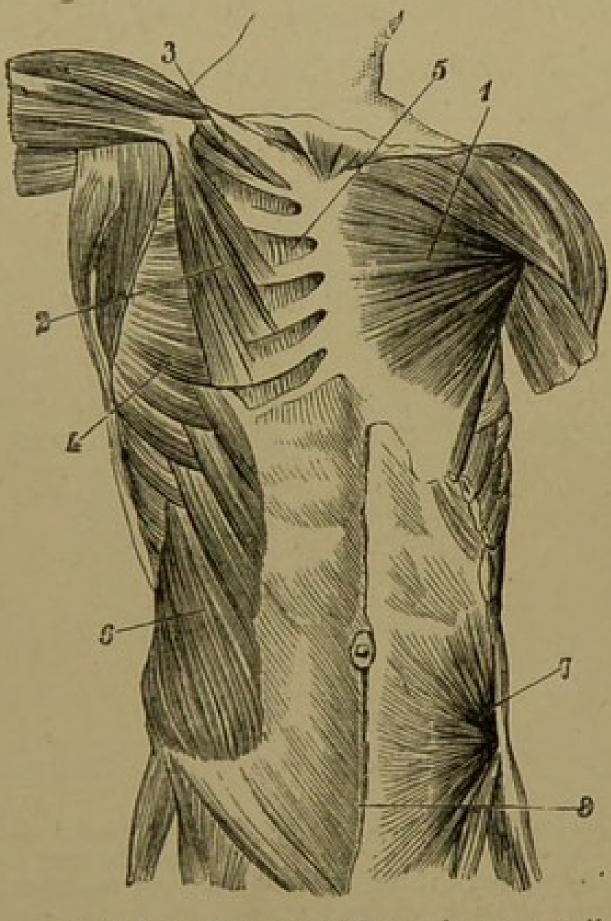

FIG. 60.—Anterior muscles of the Trunk of Man: the pectoralis major of the right side and the left external oblique being removed. 1, pectoralis major; 2, pectoralis minor; 3, subclavius; 4, serratus magnus; 5, internal intercostals; 6, external oblique; 7, internal oblique; 8, linea alba.

sition from the condition of a fish to that of a quadruped, as regards a most important group of organs.

In ourselves, the back is provided with muscles which extend along its length in a complex series of longitudinal divisions, from the middle line outwards.

The abdomen of man is inclosed and protected by successive muscular layers laid one upon another, the fibres of the successive muscles being differently directed. Thus we have (1) the external oblique (the fibres of which pass obliquely downwards and backwards), (2) the internal oblique (the fibres of which pass obliquely downwards and forwards), (3) the *Transversalis* (with transverse fibres), and (4) the *Rectus abdominus* (situated in the middle line of the body, and with fibres directed antero-posteriorly).

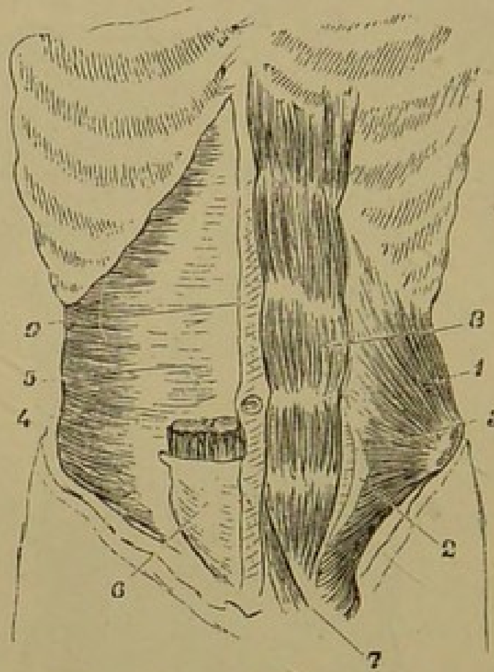

FIG. 61.—Deeper Abdominal Muscles of Man—the external oblique being removed from the left side of the body, and the internal oblique and part of the rectus also, from its right side. 1, the internal oblique; its outer tendon (2) is cut and reflected from the outside of the rectus to show its deeper tendon (3), which passes within the rectus except towards the pubis; 4, transversalis; 5, its fascin; 6, sheath of the rectus—near the pubis, the conjoined aponeuroses of the abdominal muscles pass in front of that muscle: 7, pyramidalis; 8, rectus of left side, showing the tendinous intervals, or *lineæ transversæ*.

In the frog we also meet with the vast sheets of muscle with oppositely directed fibres (the external and internal oblique), and with a median, antero-posteriorily directed rectus muscle.

A very different condition exists in fishes, where there is indeed a median antero-posteriorly directed rectus, but where the abdomen and tail are encased with a mass of muscular fibres not arranged in superimposed sheets, but as a series of narrow segments separated from each other by layers of membrane. The edges of these membranous layers, when the skin is removed, appear as a successive series of undulating lines proceeding from the back to the belly.

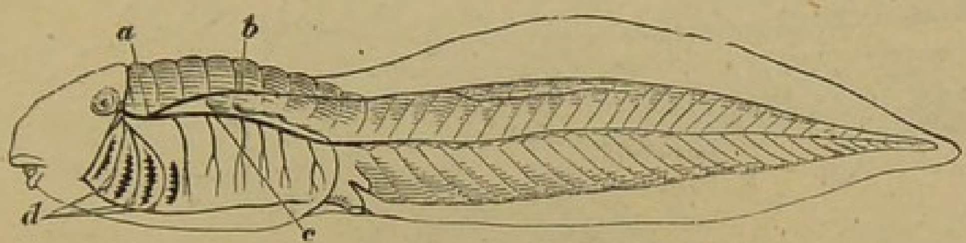

FIG. 62.—Tadpole of Bull Frog, partly dissected, to show the muscles of the tail and the branches of the 8th nerve or the *vagus*. *a*, great lateral branch giving off—*b*, a dorsal branch, and *c*, the lateral branch (or *nervus lateralis*); *d*, branches descending and passing along the branchial arches. The descending branches seen behind the branchial nerves on the side of the belly are not branches of the vagus at all, but spinal nerves, which come out from beneath the muscles and pass down under the *nervus lateralis*, and without having any communication with it.

Now the tadpole exhibits a muscular condition quite similar to that of the fish, and in the great persistent larva the axolotl, we find no truly oblique abdominal muscles, but only as it were a hypertrophied rectus.

In other species of the frog's class, which retains a tail throughout life, the marked superimposed lamellæ are distinctly developed, but more or less distinct traces are also retained of the successive membranous partitions separating the muscular segments of both the dorsal and ventral regions.

Another stage of development may be dete .d in the tail-muscles of certain reptiles.

Here the membranous partitions have become drawn out at short intervals from above downwards into a funnel-shaped condition, so that the muscular fibres enclosed, assume the forms of cones. Moreover, the apices of the membranes enclosing the cones,

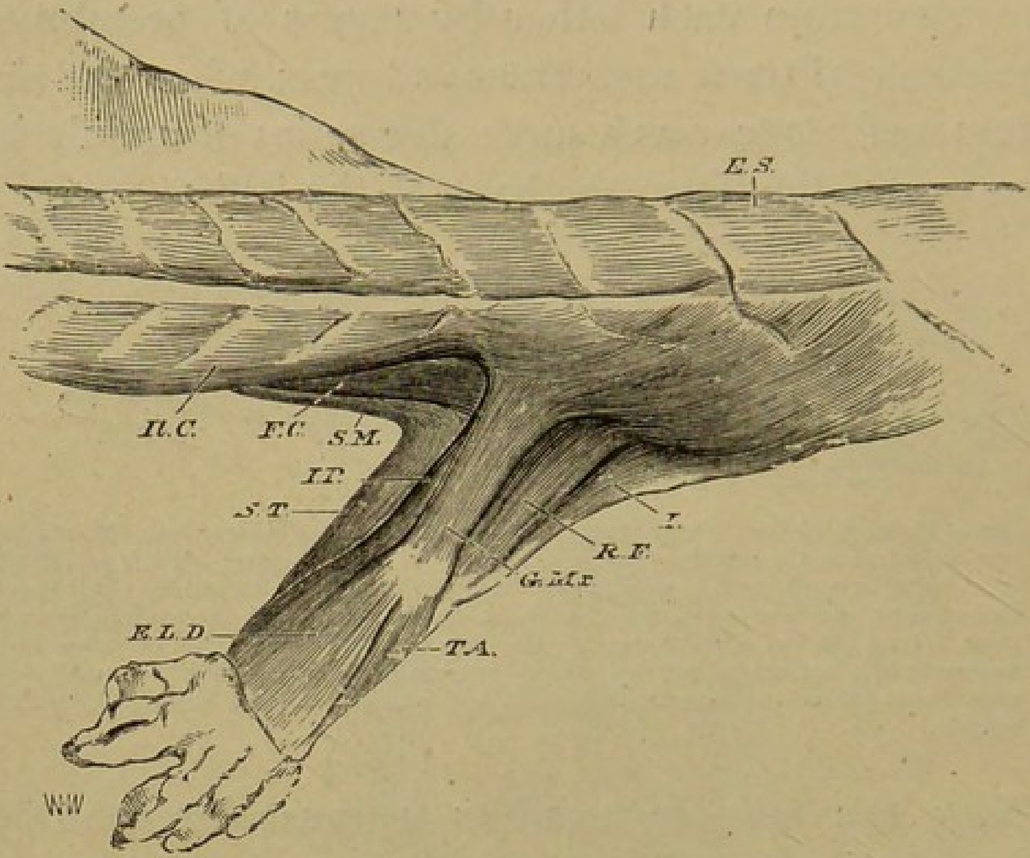

FIG. 63.—Superficial Muscles of Extensor Side of Leg and of parts of Trunk and Tail of Menopoma. *ES*, erector spinæ—directly continued into dorsal half of tail; *ELD*, extensor longus digitorum pedis; *FC*, femoro-caudal; *GMx*. probably rectus femoris; *I*, muscle resembling iliacus; *ILC*, ilio-caudal; *IP*, ilio-peroneal; *RF*, part of great extensor of thigh; *SM* and *ST*, muscles like the semi-membranosus and semi-tendinous.

become denser in substance, and so modified into ligaments.

We come thus to have a key to the process of development, by which the muscles of the back may be conceived to have arisen.

The muscles of the back may be conceived as having arisen through increasing obliquity, conical prolongation, and partial detachment (from muscle) of the separating membranous lamellæ; the produced ends becoming condensed into firm tendons directed more or less obliquely forwards.

The muscles of the abdomen may be conceived as having arisen through atrophy, in that region, of the

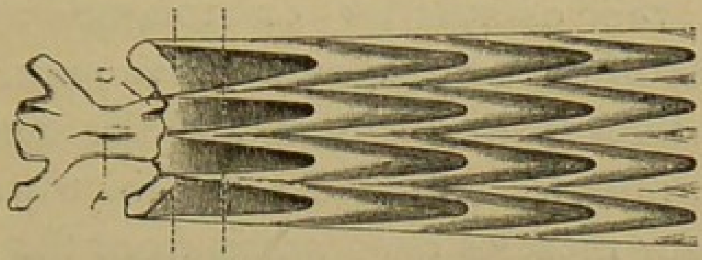

FIG. 64.—Diagram of Caudal Muscles of Right Side or Tail of *Iguana*, showing how the ventral mass resembles the dorsal part, and how the tendinous intersections of the mu cular fibres are drawn out into cones. *N*, neural spine; *H*, hypapophysial spine; *z*, zygapophysis; *t*, transverse process; 1, dorsal series of cones; 2, upper lateral series of cones; 3, lower series of cones; ventral series of cones.

separating membranes and subsequent splitting up of the muscular mass into super-imposed sheets of differently-directed fibres.

This filiation between piscine and mammalian myology could hardly have been detected but for the remarkable series of gradations which the frog's class exhibits—gradations both between species, and be-

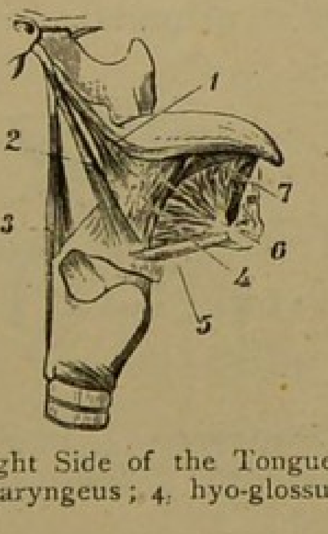

FIG. 65.—Muscles of the Right Side of the Tongue of Man. 1, stylo-glossus; 2, stylo-hyoid; 3, stylo-pharyngeus; 4, hyo-glossus; 5, genio-hyoid; 6, genio-glossus; 7, lingualis.

tween different ages and conditions of one and the same species.

The muscles connected with the human lingual apparatus are sufficiently complex. One such muscle

—the *stylohyoid*—passes downwards on each side, from a process of the base of the skull to the corniculum of the os-hyoides or tongue-bone. The tongue-bone of the frog is, as we have seen, relatively far greater than is that of man, and the same may be said of the muscles attached to it, since we have no less than four muscles descending from the skull, and implanted into it, on each side.

This fact might well be supposed to bear direct relation to the size and mobility of the frog's tongue. The tongue in the frog and toad is singularly different from the tongues of most familiar animals, in that it is not free and movable in front, but *behind.* These Batrachians take their food by suddenly throwing forwards, out of the mouth, the free hinder end of the tongue. The insect or other small animal struck by it, adheres to it, on account of a viscid saliva with which it is coated. The prey is then suddenly drawn into the mouth and swallowed.

FIG. 66.—Head of the Frog *Phyllomedusa*, showing the tongue fixed in front, but free posteriorly.

Here then is the ready explanation of the development of the *os-hyoides* and its muscles. There is a difficulty, however, in that two toads already described, the Pipa and the African form *Dactylethra* (Figs. 11 and 12), have no tongue whatever.

Moreover, there is another toad (*Rhinophrynus*) which is even more exceptional in its order than these two; in that its tongue is not free behind, but, like that of ordinary vertebrates, in front (Fig. 13).

The fact is, that the large tongue-bone of these animals serves, with the muscles attached to it, as much to facilitate respiration as nutrition.

It has already been said that the frog has no ribs by the elevation and depression of which it may alternately fill and empty its lungs. Neither does it possess that transverse muscular partition, the diaphragm, or midrif, which in man's class is the main agent in carrying on that function.

The lungs of the frog are inflated as follows:—The mouth is filled with air through the nostrils and kept shut while the internal openings of the nostrils are stopped by the tongue, and the entrance to the gullet is closed. Then, by the contraction of the muscles attached to it, the os-hyoides is elevated; and every other exit from the mouth being closed, except that leading to the larynx, air is thus driven down the glottis into the lungs.

Thus, for pulmonary respiration it is necessary to the frog to keep the mouth shut; and in this way, but for the action of the skin, the animal might be choked by keeping its mouth open.

It has been already stated that the typical segmentation of the limbs is wanting in all fishes, but present in all Batrachians that have limbs at all. Similarly, in all Batrachians that have limbs at all the muscles of those limbs have essentially and fundamentally the same arrangement as in higher animals. In the higher animals, as in man, the muscles of the limbs belong to different categories named from the kinds of motion to which their contractions give rise.

Thus, when two bones are united by a movable joint (as the thigh-bone and shin-bone), muscles which by their contraction tend to make the angle formed by such bones acute are termed "flexors." Those, on the contrary, which tend to open out such an angle are termed "extensors."

In the fore-arm of man, and allied animals, there are muscles which tend by their contraction to place the hand in a position either of *pronation* or of *supination.*

When the arm and hand hang down, the *palm* being directed forwards, the position is that of supination, and the bones of the fore-arm are situate side by side.

When the arm and hand hang down, but the *back* of the hand is turned forwards, the position is that of pronation, and the radius crosses over the ulna. When we rest on the hands and knees, with the palms to the ground, the fore-arms are in pronation.

Muscles which tend to place the fore-arm and hand in the position of pronation are termed *pronators;* those which, by their contraction, tend to render it supine are called *supinators.*

It is somewhat surprising to find in an animal so nearly related to fishes as *Menobranchus* definite flexors, extensors, pro- and supi-nators essentially like those of higher animals; and these distinctions once established, persist up to man himself with increasing complications.

The muscular conformity between the highest and lowest of typically-limbed vertebrates is strikingly shown by the structure of the thigh and leg, the

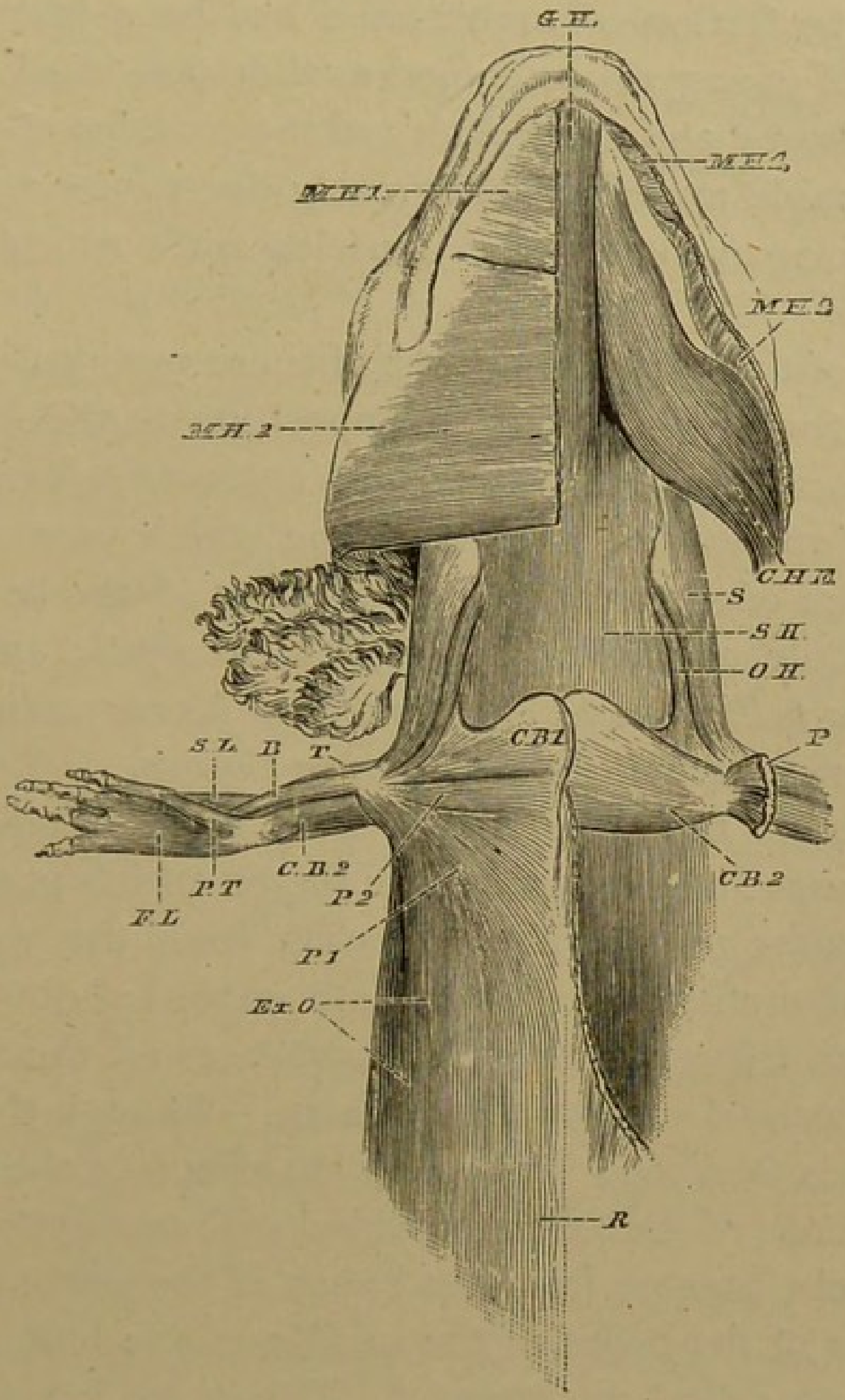

FIG. 67.—Muscles of Ventral Surface of *Menobranchus*. On the right side, superficial muscles; on the left side, deeper muscles, the mylo-hyoidei, pectoralis, and external oblique being removed. Also superficial flexor muscles of right pectoral limb of *Menobranchus*. *B*, biceps; CB^1 and CB^2, coraco-brachialis; *CHE*, cerato-hyoideus externus; *EO*, external oblique; *FL*, flexor longus; *GH*, genio-hyoid; MH^1 and MH^2, mylo-hyoideus; *OH*, omo-hyoid; *P*, P^1, and P^2, pectoralis: *R*, rectus; *S*, subclavius; *SH*, sterno-hyoid; *SL*, supinator longus; *T*, triceps.

leading muscles of these parts in the frog being so like those of man that the practice of calling them by the same name is abundantly justified.

The perfection of man's hand has been justly the theme of panegyric, esteemed as widely as it is known. The delicacy and multiplicity of the motions of which it is capable are of course greatly due to the number and arrangement of the muscles with which it is provided.

One of the most important of these motions is that of the thumb as placed in opposition to the fingers, and effected by a muscle termed *opponens pollicis.*

An "opponens" muscle is one which passes from the bones of the wrist to one or other of the bones of the middle of the hand called *metacarpals*, and the *opponens pollicis* passes of course, as its name implies, to the metacarpal of the pollex or thumb.

No other finger of man's hand is furnished with such a muscle except the little finger, which possesses an *opponens minimi digit*, passing from the wrist to the fifth metacarpal. The same condition obtains in the apes, though in them the opponens of the thumb is smaller and weaker than in man. Though the foot of man is furnished with many muscles, like the hand, yet not one of the toes is provided with an "opponens" or muscle, passing from the bones of the ankle to one or other of the bones of the middle of the foot, which latter are called metatarsals. The same is the case with the apes, except that the Orang-utan has a small "opponens" attached to the great toe.

This being premised, the foot of the Frog may well excite surprise as to its rich muscular structure. In addition to very numerous other muscles on both surfaces, every one of the toes is provided with a separate opponens muscle, each having a muscle which passes from the bones of the ankle to its middle foot bone or metatarsal.

The question naturally occurs on, beholding this prodigality of muscles — What special purpose is served by the Frog's foot? Surely mere jumping and swimming cannot require so elaborate an apparatus.

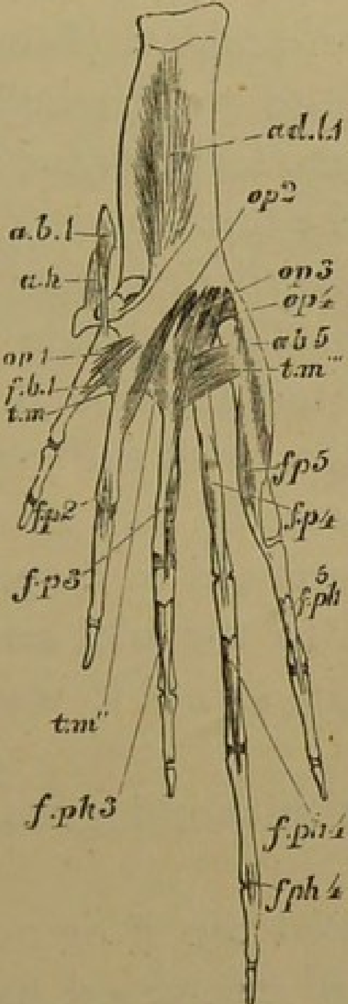

FIG. 68.—Deep muscles of exor surface of Frog's hind foot. (The numbers indicate the digits to which the muscles belong.—No. 1 indicating the first digit or great toe.) *ab*, abductors; *ad*, adductor; *fb*, flexor brevis; *fp* flexores profundi; *fph*, flexores phalangium: *op*, opponens muscles; *tm*, transverse muscles.

In fact, however, the Frog *does* make use of his feet for a purpose requiring actions no less dexterous and delicate than nest-building.

In 1872 Dr. Günther observed a Frog busily occupied, and industriously moving its hind legs in a singular manner. On approaching closely he found it had constructed for itself a shelter in the shape of a little bower, formed of dexterously interwoven blades of grass. The circumstances have been kindly transmitted to the author by the observer, in a private letter, as follows:—

"The 'nest-building' Frog was a large example of *Rana temporaria* or *esculenta* (I forget which), which I had brought into the garden behind my house. It had taken up its abode in grass, near the edge of a tank, from which the turf sloped abruptly to the level of the garden. When I first disturbed the Frog from its lair, I found that it had lain in a kind of nest, which I cannot better describe than by comparing it to the form of a hare, with the grass on the edges so arranged that it formed a sort of roof over it. Sometimes the animal returned to it, sometimes it prepared a new form close to the old one, which remained visible for several days until it was obliterated by the growing grass.

"When in its nest, nothing could be seen of the Frog but the head.

"One day I poked the Frog out of its lair; after two or three jumps it returned to the old spot, and, squatting down on the grass, by some rapid movements of the hind legs it gathered the grass nearest to it, pressing it to its sides, and bending it over its body so as to be partially hidden.

"In all these operations no material was collected by the animal for its nest, but only the growing grass was either pressed down, or arranged so as to form a complete retreat. Unfortunately, the Frog soon disappeared altogether."

It is very probable that other functions, as yet unnoticed, may be performed by these members, since, though the observation just above related is the first known observation of the kind, yet the

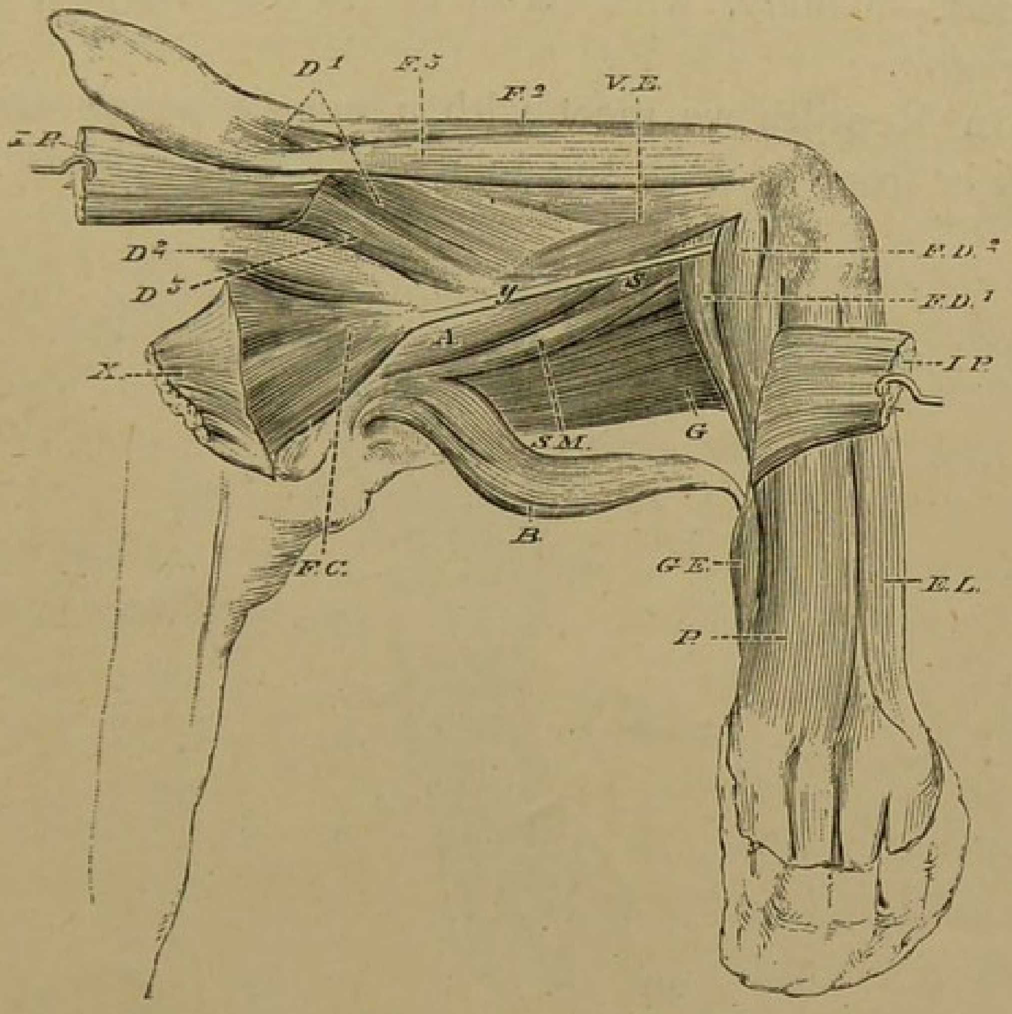

FIG. 69.—Deeper Muscles of Outer Aspect of Right Pelvic Limb of Parson's Chameleon; the ilio-peroneal cut reflected. *A*, adductor; *B*, biceps; *D*¹, gluteus primus; *D*², gluteus secundus; *D*3, gluteus tertius; *EL*, extensor longus digitorum; *F*² and *F*3, rectus femoris: *FC*, femoro-caudal; *FD*¹, flexor longus digitorum; *FD*², flexor tertius digitorum; *G*, gracilis; *GE*, gastrocnemius externus; *IP*, ilio-peroneal; *P*, peroneus; *S*, tibial adductor; *SM*, semi-membranosus; *VE*, vastus externus; *X*, gluteus maximus; *y*, tendon of femoro-caudal.

manœuvre recorded is no doubt a constant habit of the animal.

Doubtless, also, the very singular actions performed by the male *Pipa* and *Obstetricans* are performed by the help of the hinder extremities.

At the same time that the Frog shows so startling a resemblance in its leg muscles to the higher animals, it shows as striking a difference from the leg muscles of animals with which it is nearly allied,—namely, with those of its class-fellows, the *Urodela*.

In Reptiles we meet with a muscle which takes origin from beneath the joints of the tail, and is in-

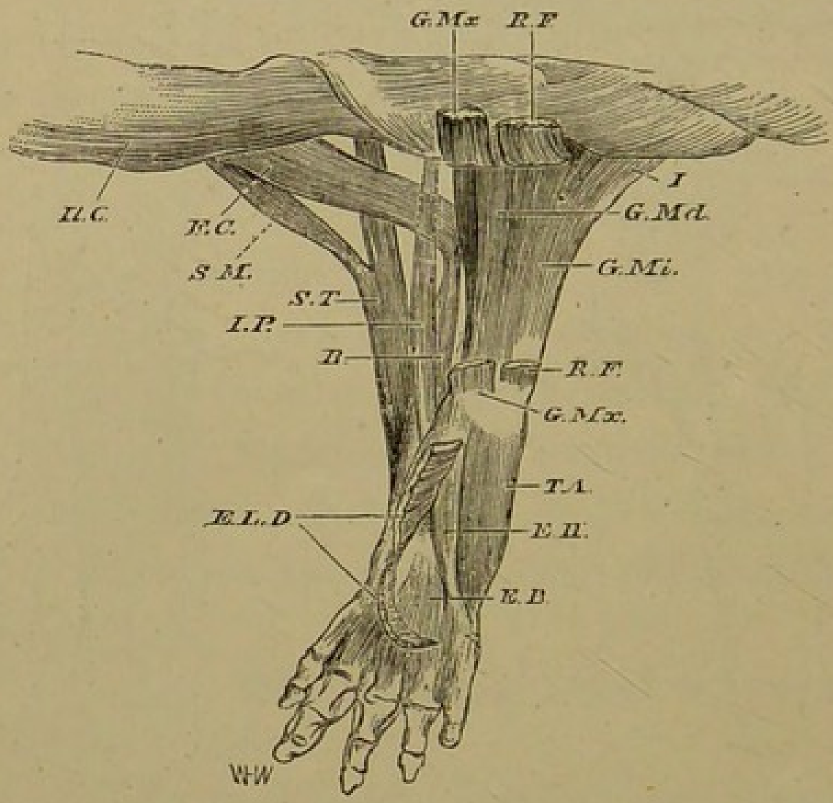

FIG. 70.—Deeper Muscles of Extensor Surface of Right Leg of Menopoma. *B*, biceps; *EB*, extensor brevis; *EH*, extensor hallucis; *ELD*, extensor longus digitorum; *FC*, femoro-caudal; *GMd* and *GMi*, muscles like the lesser glutei; *GMx* and *KF*, great extensors of the thigh; *I*, muscle resembling the iliacus; *IlC*, ilio-caudal; *IP*, ilio-peroneal; *SM* and *ST*, muscles like the semi-membranosus and semi-tendinosus respectively; *TA*, tibialis anticus.

serted with the thigh-bone, and which has no certain representation amongst mammals, and is called the *femoro-caudal*.

In the Urodela we also meet with a *femoro-caudal*, but no such structure exists in the Anoura. This is not so surprising when we recollect the abortive condition of the tail of the Frog. It might, however, have been expected that in the Tadpole, during the co-existence of the tail with the hind legs, and while it thus externally resembles an eft—such a muscle would transitorily exist. Such, however, is not the case, and the distinction is a very remarkable one.

In one point, however, the Efts resemble the Frogs, namely, in the greater number and greater complexity as well as the greater size of the muscles of the hind-limbs than of the fore-limbs. It is well known that the Efts make use of their hind-limbs in attaching their eggs to the leaves and branches of aquatic plants; and further observations may show with regard to these animals facts, as to the use of the members, as novel and interesting as the one just cited with regard to the nest-building actions of the Frog.

CHAPTER VIII.

THE NERVOUS SYSTEM OF THE FROG.

THE nervous system consists of the brain, spinal marrow, and nerves.

The whole consists of a soft, white substance, ultimately composed of minute threads, termed *nerve-fibres*, and minute round bodies called "ganglionic corpuscles."

The brain is contained in the cavity of the skull, and consists of a rounded mass made up of corpuscles and fibres, and itself contains a cavity which is a remnant of the original canal formed by the upgrowth and overclosure of the walls of the primitive groove of the embryo.

The spinal marrow (as has been said earlier) traverses the canal formed by the successive neural arches of the vertebræ, being directly continuous with the brain, which it, as it were, continues on down the back. Like the brain, it is largely composed of corpuscles, as well as fibres, and itself contains a longitudinal cavity (continuous with that in the brain), which is also the ultimate condition of the canal formed from the primitive embryonic groove.

The nerves generally (which are made up of fibres) proceed forth from the brain and spinal marrow, which latter are therefore called the *central*, or (from their position along the dorsal axis of the body), the *axial* portion of the nervous system.

All the nerves which so proceed together constitute what is called the *peripheral*, or (because going to the limbs which are appendages of the trunk), the *appendicular* portion of the nervous system.

From the brain proceed the nerves of special sense: a pair, one on each side, going to the nostrils (1, the *olfactory nerves*), another pair going to the eyes (2, the *optic nerves*), and a third pair going to the ears within the skull (3, the *auditory nerves*). Other nerves go to the tongue and palate, ministering to taste, and again others to the little muscles (orbital muscles), which move the eyeball in various directions, and to different parts of the face.

The nerves which come forth from the spinal marrow are called spinal nerves. They proceed out in pairs (one on each side), and are distributed to the limbs and trunk.

Each nerve consists of fibres, of two sorts proceeding respectively from the ventral (in man anterior), and the dorsal (in man posterior) aspects of the spinal marrow. But these two kinds of fibres are distributed side by side in the ramifications and distributions of each nerve.

The fibres which come ultimately from the dorsal aspect of the spinal marrow are those which carry inwards the effect of a stimulus applied towards their ultimate termination, and are therefore called *afferent*, or *sensory*.

The fibres which come ultimately from the ventral aspect of the spinal marrow, are those which carry an influence outwards, and produce a contraction in the muscles, and are therefore called *efferent* or *motor*.

It is the nervous system of the frog, rather than any other set of its organs, which has especially excited interest and attention. It is especially to the relations *inter se*, of the parts of this system that inquiry has been directed. The relations, that is, of its central or axial portion (the brain and spinal column) to its peripheral or appendicular portion (the nerves of the body and limbs).

In the ever memorable year 1789, Galvani accidentally discovered in the separated legs of certain frogs, prepared for broth, those motions produced by irritation of the exposed great nerve of the thigh, now so familiar to most. This action was long called galvanism, after this observer, not, however, that he was absolutely the first to notice a fact of which he was but a re-discoverer—Swammerdam as long ago as 1658 having observed such motions.

They are generally considered as demonstrating the purely "reflex action" of the nervous system—the responsive action, that is, upon muscles, of nervous centres acted on by external stimuli without the intervention of sensation.

It is affirmed that not only will a decapitated frog endeavour to remove an irritating instrument by means of its hind legs and feet; but that if a caustic fluid be applied to a spot easily reached by one foot, the decapitated frog will apply that foot to the spot. More than this, if that foot be cut off it will move the stump as before, seeking to reach the spot and failing so to do, will then apply the other foot to the irritated locality.

These, and such experiments, are of course conclusive, if the common assumption be conceded that the brain is the indispensable nervous instrument of sensation.

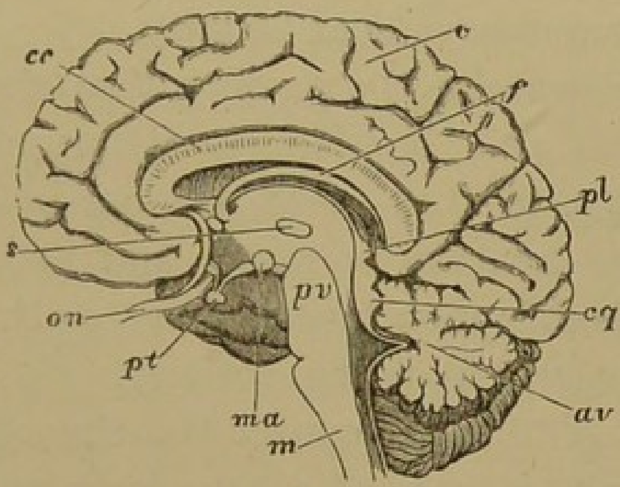

FIG. 71.—The Brain of Man as seen when a Vertical Longitudinal Section has been made through its middle. *Av*, arbor vitæ of the cerebellum; *c*, cerebrum; *cc*, corpus callosum; *cq*, corpora quadrigemina; *f*, fornix (between the fornix and the corpus callosum is the septum lucidum); *m*, medulla oblongata; *ma*, corpus mammillare; *on*, optic nerve; *pl*, pineal gland; *pt*, pituitary body; *pv*, pons Varolii; *s*, soft or middle commissure.

It is possible, however, that the faculty of sensation may be subserved by the spinal cord without the brain, and if so, all these much vaunted experiments are valueless as regards the truth of pure reflex action, not but that they are of extreme interest, as showing what may be done in lower animals without the intervention of any brain action whatever.

Mr. G. H. Lewes has long contended against the attribution of sensation to the brain exclusively, and Dr. Bastian has recently supported and enforced similar views.

The latter remarks in his "Beginnings of Life,"—"instead of accepting the popular view, that the brain is the organ of mind, I believe it would be nearer the truth to look upon the whole nervous system as the organ of mind."

Dr. Bastian here uses the word "mind," not as denoting a rational intellect, but as a generic term equivalent to nervous psychical activity.

It may be remarked in passing that these views of Messrs. Lewes and Bastian closely approximate, as far as they go, to that most rational belief that the soul of every creature is whole and entire in every atom of its bodily structure so long as the latter preserves its integrity and vital activity.

The brain of the frog consists of the same essential parts as does the brain of all the vertebrate animals, including man. In the form and in the proportions of those parts, however, it differs extremely from the higher animals (and above all from man), and resembles the lower forms—the brain of the frog (and of Batrachians generally) offering a much closer resemblance to that of a lizard than to that of a mammal.

The brain of man consists of the following fundamental parts:

1. A pair (one on each side) of small rounded bodies, each connected, by a long stalk, with the mass of the brain, and each shaped somewhat like a life-preserver. These are the "*olfactory* lobes," and

from the swollen head of each proceed the delicate nerves of smell.

2. An enormous pair of folded masses, which form the great bulk of the human brain, and are called the *cerebral lobes* or hemispheres. These are so large and preponderant in man, as to hide every other part of the human brain when that organ is viewed from above.

3. A relatively very small portion, but one easily recognized, since it supports two conspicuous little bodies. One of these (Figs. 69, 70, 71, *pl*) is called the *pineal gland*, and projects more or less upwards; the other (Figs. 69, 70, 71, *pt*) projects downwards, and is called the *pituitary body*.

4. An also very small portion relatively, is distinguished by bearing certain small prominences (Fig. 69, *cq*, and Fig. 70, *na* and *te*) placed behind the pineal gland and called *corpora quadrigemina*.

5. A rounded mass of finely-folded brain-substance, placed at the lower part of the back of the head, beneath the hinder portion of the cerebral hemispheres. This is called the *cerebellum*, and when cut through exhibits singular, radiating, tree-like markings, due to the infoldings of the surface of the organ, and called the *arbor vitæ* (Fig. 70, *av*).

6. That part which directly continues the brain into the spinal marrow (Fig, 71, *m*). It is overlapped by the cerebellum, and contains that portion of the remnant of the primitive nervous canal, which is named the *fourth ventricle*. This sixth fundamental part of man's brain is called the *medulla oblongata*.

On turning to the brain of the frog from that of man, it is at first sight difficult to find out the resemblances, and to determine which portions of the one answer to definite regions of the other. (Fig. 74.)

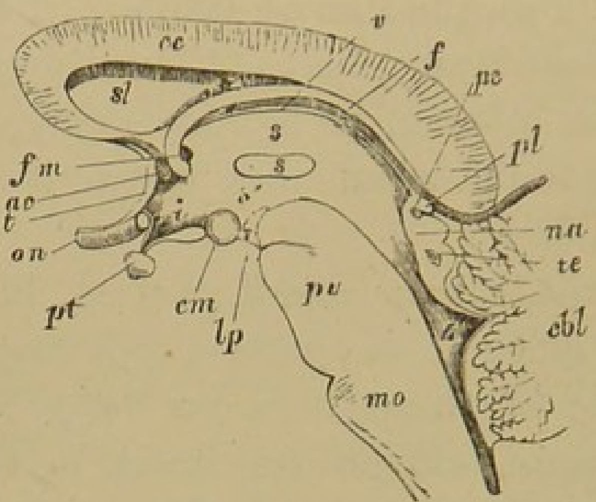

FIG. 72. Enlarged and Diagrammatic View of a Vertical Section carried through the Corpus Callosum (of Man) and the parts below. *ac*, anterior commissure; *cc*, corpus callosum; *cbl*, cerebellum; *cm*, corpus mammillare; *f*, fornix; *fm*, foramen of Monro; *i*, infundibulum; *lp*, locus perforatus medius; *mo*, medulla oblongata; *na*, nates; *on*, optic nerve; *pc*, posterior commissure; *pv*, pons Varolii; *pl*, pineal gland; *pt*, pituitary body; *s*, soft, or middle commissure; *sl*, septum lucidum; *t*, lamina terminalis; *te*, testes; *v*, velum interpositum (between it and the fornix is a space enclosed by the folding over of the cerebrum upon the roof of the third ventricle); 3, upper, and 3' lower part of the third ventricle; 4, fourth ventricle—between them is the *iter a tertio ad quartum ventriculum*.

In the earliest conditions of the human brain the resemblance is much more marked and obvious; it is later that the correspondence between the brain of the frog and that of man becomes so disguised through the unequal growth of different portions of the organ in the human brain as it advances in its growth and development. The same six successive portions, however, exist in each.

1. In the frog the olfactory lobes acquire a much larger relative size, and they retain permanently an internal cavity which exists only transitorily in man.

2. The cerebral lobes (or hemispheres) exceed those just noticed, but are insignificant indeed, when compared with the corresponding human structures. They

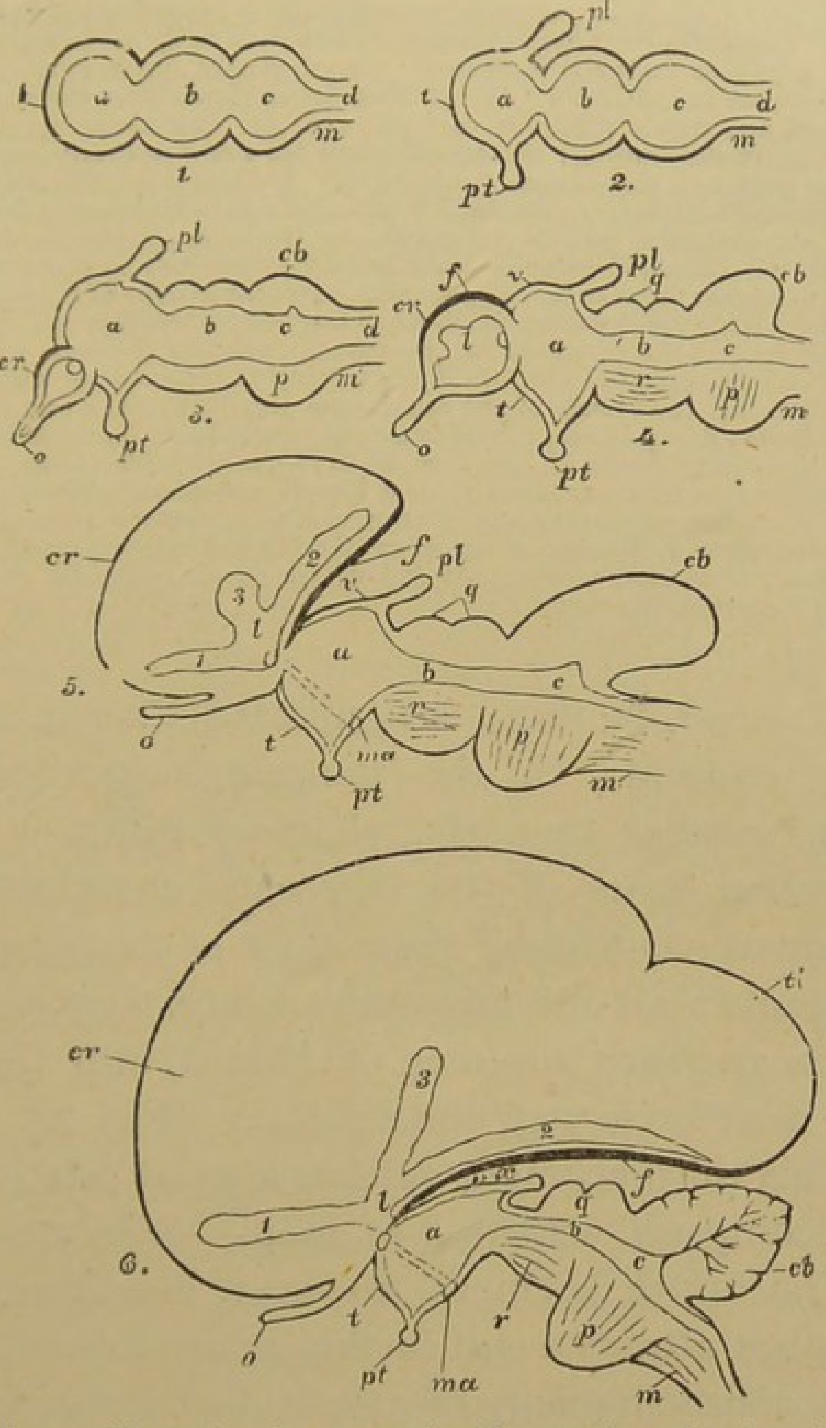

FIG. 73.—Diagram illustrating the progressive Changes that take place during successive stages of the Development of the Brain of Man. 1. The brain in its very early condition, when it consists of three hollow vesicles the cavity of which is continuous with the wide cavity (*d*) of the primitive spinal marrow (*m*). The brain substance forms an envelope of nearly equal thickness throughout. 2. Here the first vesicle or fore-brain has developed the pineal gland (*pl*) above and the pituitary body, (*pt*) below. The wall at the anterior end of the first vesicle (or fore-brain) is the lamina terminalis (*t*). 3. This figure shows the cerebrum (*cr*) budding from the first vesicle, its anterior part (*o*) being prolonged as the olfactory lobe (the so-called olfactory nerve), the cavity of the cerebrum (or incipient lateral ventricle) communicating with that of the olfactory lobe in front and with that of the first cerebral vesicle (third ventricle) behind. The latter communication takes place through the foramen of Monro. The walls of the three primitive vesicles are becoming of unequal thickness, and the cavity (*b*) of the middle

vesicle (*iter a tertio ad quartum ventriculum*) is becoming reduced in relative size. 4. The cerebrum is here enlarged, and the inequality in thickness of the wall of the primitive vesicle is increased. The thickened upper part of the wall of the cerebrum is the fornix (*f*). 5. This figure shows the cerebrum still more enlarged, and with a triradiate cavity (*l*, 1, 2, 3). The fornix has now come to look slightly downwards; dotted lines indicate the downward extension of its anterior part, into the corpora mammillaria. 6. Here the cerebrum is still more enlarged and backwardly extended. The fornix is shown bordering the descending cornu and extending into the temporal lobe (*tl*) of the cerebrum, which lobe is destined to descend (when the brain is fully developed) so much more that it comes to advance forwards. The fornix borders the margin of the very thin outer wall of the descending cornu, which when torn forms the fissure of Bichat. The bending back of the cerebrum has now almost enclosed (between the fornix and the velum) the space (*x*) which in Fig. 4 is widely open, making what is morphologically called the outside of the brain come practically to be in its very centre. *a*, fore-brain; *b*, mid-brain; *c*, hind-brain; *cb*, cerebellum; *cr*, cerebrum; *d*, cavity of the medulla; *f*, fornix; *l*, lateral ventricle; *m*, medulla oblongata; *ma*, corpora mammillaria; *o*, olfactory lobe; *p*, pons Varolii; *pl*, pineal gland; *pt*, pituitary body; *q*, corpora quadrigemina; *r*, crura cerebri; *t*, lamina terminalis; *tl*, temporal lobe of the c rebrum; *x*, space, enclosed by the extension backwards of the cerebrum; 1, anterior cornu of lateral ventricle; 2, its middle or descending cornu; 3, its posterior cornu.

may, however, be more insignificant than in the frog, as, for example, in the lamprey, where they are actually smaller than the olfactory lobes. In that the cerebral lobes of the frog each contain a cavity (the lateral ventricles) they have a character which is constant in all animals above fishes, they open by a common aperture (foramen of Monro) into the cavity of the next brain segment behind. (Fig. 74, *b*.)

3. This third segment retains a great relative magnitude compared with that of man. (Fig. 74, *d*.)

4. The fourth segment, however, consisting of the optic lobes, attains a still further relative development, though consisting only of two bodies instead of four, but these contain a cavity not found in the *corpora quadrigemina* of the human brain. (Fig. 74, *g*.)

5. The fifth segment, the cerebellum, is very small, and smaller than the same part in animals both higher and lower in the scale; indeed, in the frog class, this organ may be said to be at its minimum. When cut it exhibits no trace of an *arbor vitæ*. (Fig. 74, *h*.)

This fact has a special interest as bearing on alleged functions of this portion of the brain.

It has been asserted by some that the cerebellum ministers to the sexual functions; by others that this part co-ordinates and directs locomotive movements; and quite lately, that it is related to movements of the eyes.

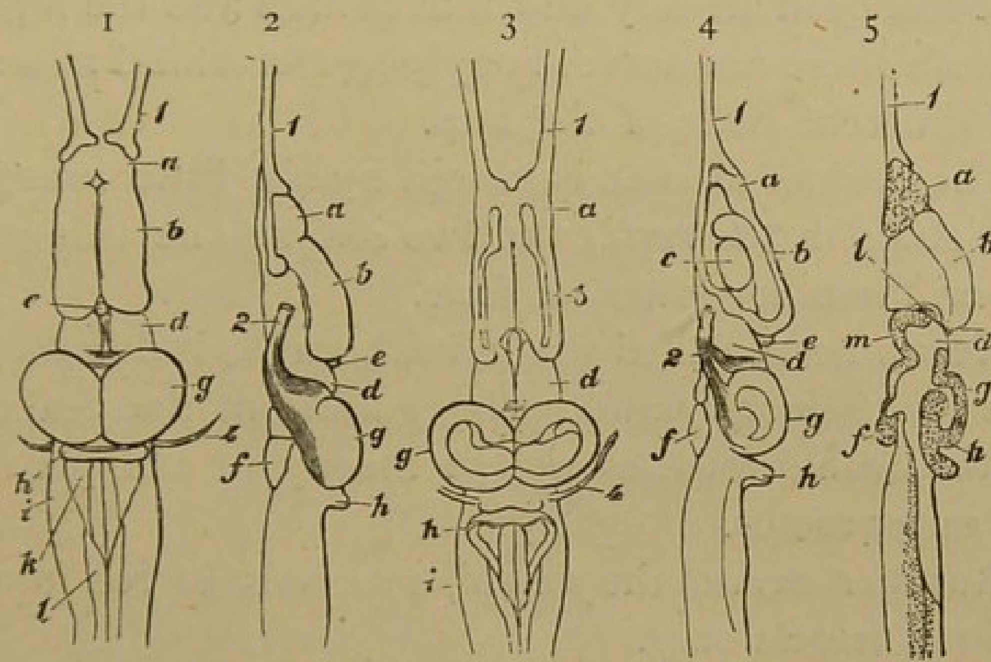

FIG. 74.—Brain of Bull Frog in various views. 1, Dorsal view. 2, Lateral view. 3, Transverse horizontal section showing the cavities of the olfactory cerebral and optic lobes. 4, Longitudinal section a little to the left of the median line. 5, Longitudinal section in median line. The corpus striatum, *c*, is here exposed to view and also a body, *g*, within the optic lobes. 5, Longitudinal section in median line. In all five figures :—1, Olfactory nerve; 2, optic nerve: 4, auditory nerve; *a*, olfactory lobe; *b*, cerebral lobe; *c*, corpus striatum; *d*, optic thalamus; *e*, pineal gland; *f*, pituitary body; *g*, optic lobes; *h*, cerebellum; *i*, medulla oblongata.

The first two of these hypotheses seem to be completely overthrown by our frog. In the first matter there is anything but a deficiency of energy and activity; and as to the second, many reptiles are less active and continuous than the frog in their locomotive efforts. As to the third hypothesis, it should be remembered that the eyes of the frog are large and very moveable, as also that they require a power of ready adjustment to enable the animal to secure its insect prey.

6. The sixth and last segment of the brain, the medulla oblongata, is also relatively large, and is exposed to view through the rudimentary development of the cerebellum which, as has been said, overlaps it in man. (Fig. 74, *i.*)

It has been already said, that in man and the higher animals there are nerves supplying the orbital muscles and different parts of the face.

The eyeball in man is moved by six little muscles, four straight (the *recti*) and two *oblique*, one being the upper, the other lower, oblique.

Now a nerve called the *third*, because it follows the first two (olfactory and optic), goes from the brain to all the orbital muscles except the upper oblique and the outer rectus.

Another nerve, the *fourth*, proceeds to the upper oblique muscle only.

The *fifth nerve* is a very large one, and supplies the nose, tear-gland, eyelids, upper and lower jaws, tongue, and teeth.

The *sixth nerve* is a very small one indeed, being exclusively applied to the outer rectus muscle of the orbit.

The *seventh nerve* is, in human anatomy, reckoned as part (the *portio dura*) of the auditory nerve. It sends fibres to the face.

The *eighth nerve* is a very complex structure, and consists of, at least, three nerves united together, all arising from the medulla oblongata. It sends branches to the parts about the throat as well as to the organ of voice, to the lungs, the stomach, and the heart.

The nerves of the frog exhibit certain intermediate conditions, like those we have seen to exist in various other parts of its anatomy.

In the higher vertebrate animals, as in Man, the muscles which move the eyeball are supplied by three distinct nerves, termed respectively the 3rd, 4th, and 6th. The 5th nerve being a very large and complex one, sending branches to various parts of the head and its organs.

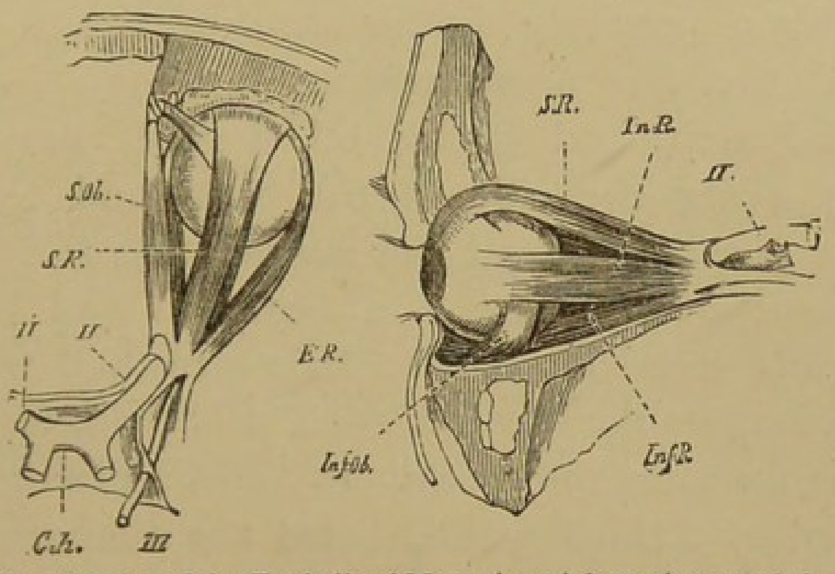

FIG. 75.—The Muscles of the Eyeballs of Man, viewed from above and the outer side. *R.S.*, the superior rectus: *Inf.R.*, the inferior rectus; *E.R.*, the external rectus; *In.R.*, the internal rectus; *S.Ob.*, the superior oblique; *Inf.Ob.*, the inferior oblique; *Ch.* the chiasma of the optic nerves (*II.*); *III.*, the third nerve, which supplies all the muscles except the superior oblique and the external rectus.

Now in the frog there is no distinct 6th nerve, it being replaced by an extra branch of the 5th nerve. This modification, however, is but one step towards a condition which obtains in the Mud-fish (*Lepidosiren*), when all these three nerves are quite blended with one division (the Ophthalmic) of the 5th nerve.

Again in the higher Vertebrates, as in Man, the 8th nerve is a very large and complex one, and is distributed as in him. It is also so distributed in the adult frog.

In the tadpole, however, this nerve shows a very different arrangement. After issuing from the skull this nerve sends a branch down the outer side of each branchial arch and then gives off a very long one, which extends laterally, *i.e.* along the side of the body and tail.

Nothing like this exists in any Beast, Bird, or Reptile, but when we come to the class of Fishes we encounter a precisely similar state of things. Here we find the 8th nerve sending a branch to each branchial arch, and giving off a great nerve proceeding along the side of the body and tail, and on that account named the *nervus lateralis.*

The eye of the frog is a beautiful and brilliant object, and relatively large. It is furnished with two eyelids, but, unlike those of man, it is the inferior one which is the more moveable. In addition to these it is defended by a third eyelid, called the nictitating eyelid, which is similar to that one which may be seen (if watched for) so frequently and rapidly to cross the eye of birds, *e.g.* of a hawk.

This structure, however, is no mark of affinity to birds, as it is one which reappears, when wanted, in widely different forms. Thus we find it in the whale, *i.e.* in the highest class of the Vertebrate sub-kingdom, and in certain sharks, *i.e.* in the lowest class of the same.

Eyelids do not exist in all members of the frog's class. Even in its order they are extremely minute, in *Pipa* and *Dactylethra,* which have very small eyes.

In *Amphiuma* they are completely wanting, and in *Proteus* and in the *Ophiomorpha* the minute eyeballs are covered with the ordinary and unchanged skin of the head.

The ear of the frog's class presents us with the incipient condition of that part as an organ destined to respond to sonorous vibrations conveyed to it by the atmosphere.

In man the internal ear (enclosed in the densest bone of the skull, named, from its density, "petrous") is a very complex organ. The aperture, surrounded by the folds of the external ear, leads by a canal towards a cavity called the tympanic cavity, which cavity is shut off from the exterior by the tympanic membrane (or drum of the ear), which stretches across the canal at a considerable distance from its external aperture. On the inner side of the tympanic cavity lie the convoluted tubes (richly supplied with nerves) which constitute the real organ of hearing or internal ear.

Although the tympanic cavity is shut off from the exterior by the tympanum, it nevertheless is not altogether shut off from the exterior, since it communicates with the back of the mouth by a long and narrow canal termed the Eustachian tube.

It is the existence of these Eustachian openings into the ear from the mouth which causes people when intently listening to keep their mouth slightly open.

In the frog there is no such external canal, but the tympanum is plainly to be seen in the way already described, on the side of the head, covered only by a slightly striated portion of the skin of the body. The Eustachian tube, however, still exists in the frog, though it is short and wide, and the opening of each is to be seen on one side of the back of the mouth.

This condition of things, however, does not exist in all the members of the frog's order, still less of his class. But in *Proteus, Siren*, and *Menobranchus* there is no tympanic cavity whatever, and the organ of hearing is simply imbedded in the skull, and probably responds but to sonorous vibrations conveyed to it by the denser aquatic medium, and not at all, or but very imperfectly, to those of the atmosphere.

In the ordinary efts we still meet with an Eustachian canal, but the tympanum is absent.

In the frog's own order, as in *Pelotates* and *Bombinator*, we may fail to find any tympanum, while the Eustachian tubes are all but obliterated, being reduced to the most minute dimensions.

Another condition, however, may be presented which offers a singular contrast, and is the more remarkable from the widely separated geographical situations of the forms which present it. In the South American *Pipa*, as well as in the South African *Dactylethra*, the two Eustachian tubes run together and open at the back of the mouth, by a median and common aperture.

Strange to say, this is the very condition which exists in birds, though most certainly it cannot be taken as any sign of affinity. In the crocodile these tubes have also a common median opening, but, unlike birds, each tube has also its own lateral opening into the throat, so that there come to be three Eustachian openings.

Can the resemblance between *Pipa* and *Dactylethra* in this matter be taken as a serious indication of genetic affinity, in spite of the wide, deep, and probably ancient Atlantic which rolls between the two species now?

This is a question which cannot be confidently answered, seeing in how many other instances structural peculiarities have evidently had an independent origin. Nevertheless, the fact that these two genera agree also in the small size of the eyes, rudimentary eyelids, and vastly expanded sacral transverse process would seem to point to some ancestral and fundamental relationship. If so, however, it is remarkable that no other such forms, or no intermediate ones should have been preserved, seeing that neither kind can be suspected of having migrated to its own habitat from the existing habitat of the other; and therefore that forms similar to that from which we may, if we please, conceive both to have been derived must have had a more or less widely extended geographical distribution and have been numerous in order to have given origin to genera in many respects so different as the two in question.

CHAPTER IX.

THE CIRCULATION OF THE FROG.

NOT only every animal, but every living being, requires, in order to carry on the functions of life, to interchange some of the gaseous elements of its body with gases of the medium (air or water) in which it happens to live.

Another function of extreme generality is that of conveying to all the parts and organs of the body nutritious matter for their growth or for the repair of those destructive effects which the processes of life inevitably produce in them.

In all members of the highest sub-kingdom of animals (*i.e.* in all Vertebrata) these processes of gaseous interchange and nutrition are effected by means of closed vessels, along which the stream of nutritious fluid (the blood) is continually carried in a definite and constant course. During some or other part of that course the blood becomes exposed to conditions specially favourable to the gaseous interchange, the blood parting with carbonic acid gas and obtaining in its place an increased supply of oxygen.

This process of blood oxygenation is termed respiration, and the organs which subserve it are termed respiratory or breathing organs. Such organs in man are the lungs. The central organ of circulation in man is, as all know, the heart, which is a muscular organ, divided into four chambers, or cavities.

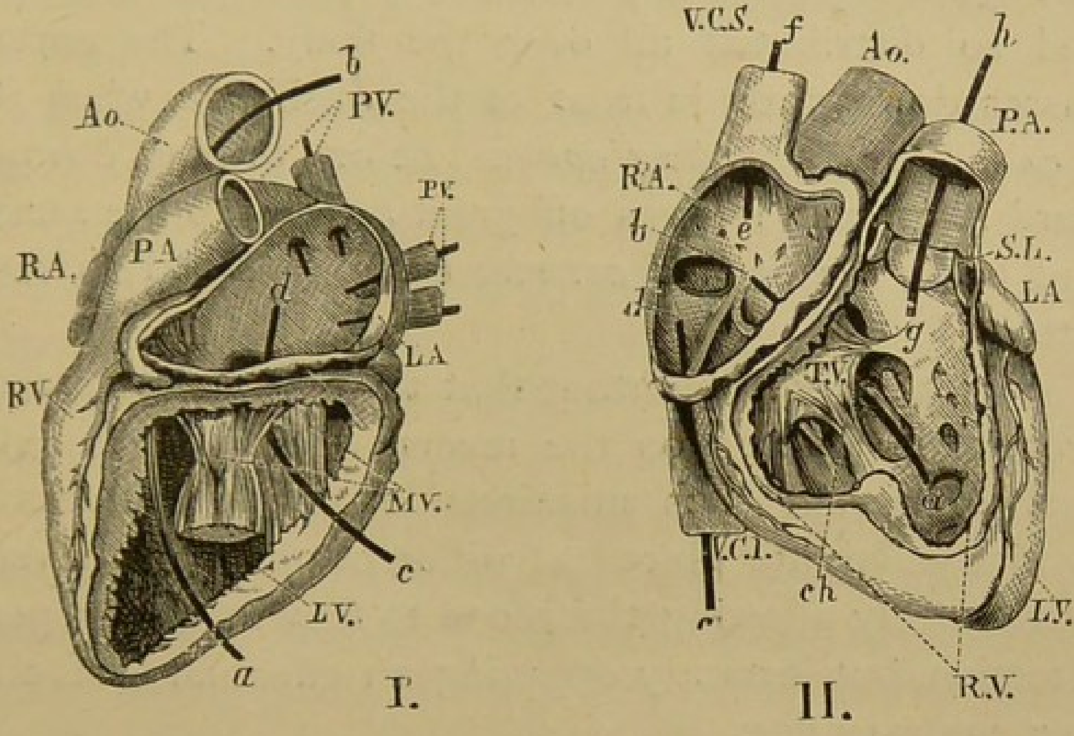

FIG. 76.—I. The left side; and II. the right side of the Heart of Man dissected. I.—*LA*, the left auricle; *PV*, the four pulmonary veins; *cd*, a style passed through the auriculo-ventricular aperture; *MV*, the mitral valve; *ab*, a style passed through the left ventricle into the aorta; *RA*, *RV*, parts of the right side of the heart: *PA*, pulmonary artery.
II.—*RA*, the right auricle; *VCS*, superior vena cava; *VCI*, inferior vena cava, the styles, *fe*, *cd*, being passed through them into the auricle; *ab*, style passed through the auriculo-ventricular aperture; *TV*, tricuspid valve; *RV*, right ventricle; *SL*, semi-lunar valves at the base of *PA*, the pulmonary artery, through which the style *gh* is passed; *LA*; *LV*, auricle and ventricle of the left side of the heart.

These chambers are called "auricles" and "ventricles," and there are two of each—there being an auricle and a ventricle on the right side and also on the left.

Blood that has performed its nutritive functions, and is therefore charged with carbonic acid gas, is called venous blood, and is conveyed by the veins to the right auricle, whence it passes into the right ventricle, which sends it to the lungs for purification.

The oxygenated, or arterial blood, is returned from the lungs to the left auricle, and hence it is directly transmitted to the left ventricle, whence it is driven through the great artery (the *aorta*) into other arteries, and so distributed all over the body. The aorta passes downwards in front of the backbone, when it is called the *descending aorta*. Before turning downwards, however, it gives off great arteries to the arms and head, the *carotid arteries* carrying blood to the latter.

Now it is very important that the blood should not proceed in a direction the reverse of that indicated, and to prevent such misdirection, or regurgitation, special valves are placed at different openings; these valves freely allowing the blood to flow in the proper direction, but instantly opposing an effectual obstacle to a contrary flux.

The openings of the auricles into the ventricles are guarded by valves, as also is the opening of the left ventricle into the aorta, and that of the right ventricle into the artery going to the lungs.

The valve which guards the entrance into the right ventricle is called *tricuspid*, and consists of three flaps attached by delicate tendinous cords in such a way as to hinder the tending backwards of the flaps into the right auricle, and so allowing the blood to flow back into that chamber.

The valve which guards the entrance into the left ventricle is called *mitral* (from a fancied resemblance to a bishop's mitre), and consists of two flaps. The aperture leading from the left ventricle to the aorta is guarded by three crescentric flaps—called the "*semilunar*" valves of the aorta.

In man the whole of the blood is sent to the lungs for purification during each circuit of this most important fluid, and every organ is supplied with oxygenated blood.

If in any animals the process of purification is incomplete, it is manifestly desirable that these organs of the body, the functions of which are the most important, should be supplied with that part of the blood which is pure. This consideration eminently applies to the brain, the director and controller of the entire body.

Now all birds and beasts without exception, share with man this perfect aeration of the entire blood, the whole of the blood in the classes *Mammalia* and *Aves* being purified in the lungs before being distributed to the body.

The conditions by which the frog, at the various stages of its existence, oxygenates its blood and directs the purified stream in the most desirable manner, are curious and instructive.

It is generally known that the lower air-breathing Vertebrates (Reptiles and Batrachians) have the heart less completely divided than in the higher classes, so that the oxygenated (or arterial) blood and the unoxygenated (or venous) blood become mixed in the single or imperfectly divided ventricle.

It might well be supposed, and in fact has generally been so, that in animals with a heart so imperfectly divided, the blood sent to the lungs would be necessarily a mixture of venous and arterial fluid, and similarly that the blood distributed by it to all the organs and parts of the body is alike a mixture of pure and impure fluid.

In fact, however, this is by no means the case, and in the frog, in spite of the reception into a single chamber of both venous blood from the body, and of arterial blood from the lungs, special mechanical arrangements effect such a definite distribution of the two sorts of blood, that the unoxygenated fluid from the body is sent to the purifying respiratory surfaces (lungs and skin), and the pure oxygenated blood alone goes to the head and to the brain.

For the detection of this beautiful mechanism we are indebted to the careful investigations of Ernst Brücke.[1]

The heart of the frog consists of a right and left auricle (divided by a delicate septum), both opening into a single ventricle. From the latter proceeds an aortic root (bulbus aortæ) which gives rise to three arterial trunks on each side.

The first of these, or carotid trunk (1), ends in an enlargement (*a*) termed the carotid gland, of spongy structure, which gives rise to two arteries, one the lingual (*l*), the other (*c*) the carotid which goes to the head and brain.

The second, or systematic trunk (2) meets its fellow of the opposite side beneath the spine, and thence

[1] "Beiträge zur vergleichenden Anatomie und Physiologie der Gefäss-Systemes." In the third volume of the "Denkschriften der Mathematisch-Natur-wissenchaftlichen Classe der Kaiserlichen Akademie der Wissenschaften." Vienna: 1852.

passes backwards as the great dorsal (in man descending) aorta, giving off arteries to all parts of the body.

The third, or pulmo-cutaneous trunk (3) ends by dividing into two arteries. The anterior of these (*r*) goes to the skin (which, as we have seen, is in the

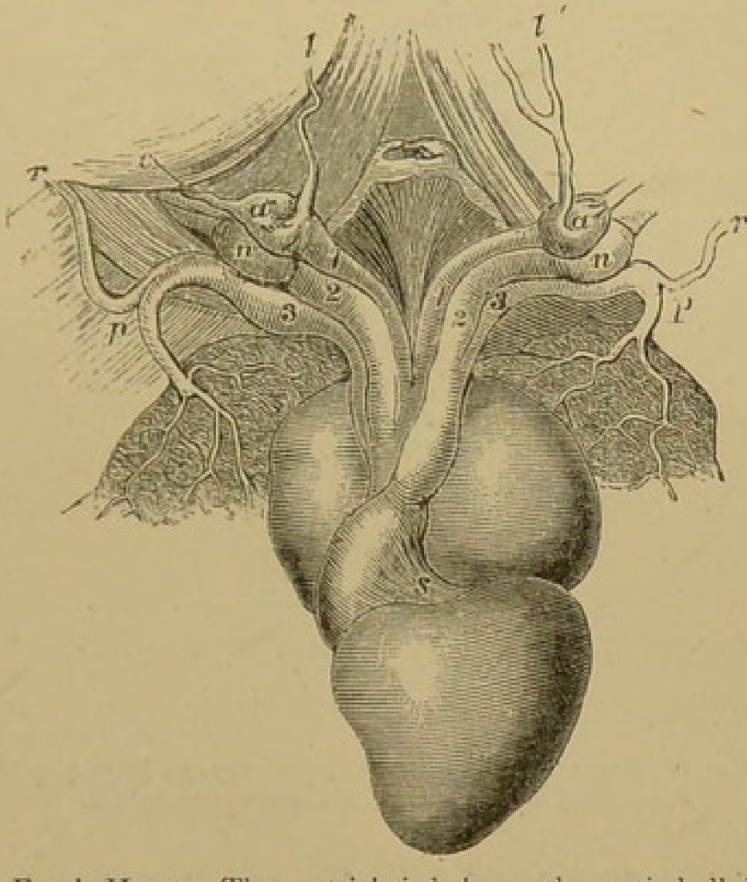

FIG. 77.—The Frog's Heart. The ventricle is below *s*, the aortic bulb is on the left of *s*, and ends in six aortic trunks, three on each side. The first of these (1) ends in the carotid gland (*a*), whence spring the lingual (*l*), and the carotid (*c*), arteries The second trunk (2) is the root of the great dorsal aorta. The third trunk (3) ends in the pulmo-cutaneous artery (*r*), and the pulmonary artery (*p*), which is shown sending ramifications over each lung.

frog an important agent in respiration), the posterior one (*p*) goes to the lungs.

The heart itself is of a more or less spongy texture, but the main cavity of the single ventricles opens at its extreme right into that of the aortic bulb (*c*). In close proximity to the opening are the openings from the right (*b*) and the left (*a*) auricles respectively.

The aortic bulb is constitutionally divided by a movable septum (Fig. 79, *s*) in such a way, that the passage on the right side of it leads to the carotid and systematic arterial trunks, while the passage on

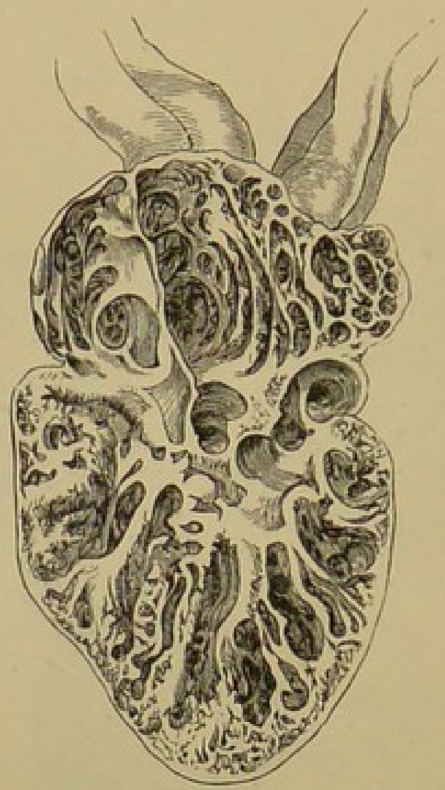

FIG. 78.—Section of Heart; *a* and *b*, openings of the auricles into the ventricle; *c*, opening of the aortic bulb into the ventricle.

the left side of it leads to the third pair of trunks—namely, those ending in the pulmonary and cutaneous arteries; moreover, there is a valve in the first of these two passages which tends to retard the flow of blood (*v*).

The consequence of these arrangements are as follows:

When the auricles contract, the venous blood from the right auricle (*RA*) is sent into both right and left passages of the bulb, but by the action of the valve (*v*), and by the structure of the carotid gland, the blood is checked on the right side (*ip*), while on the left it runs freely into the pulmo-cutaneous trunks (*r* and *p*), and thus the respiratory structures receive unmixed venous blood for purification.

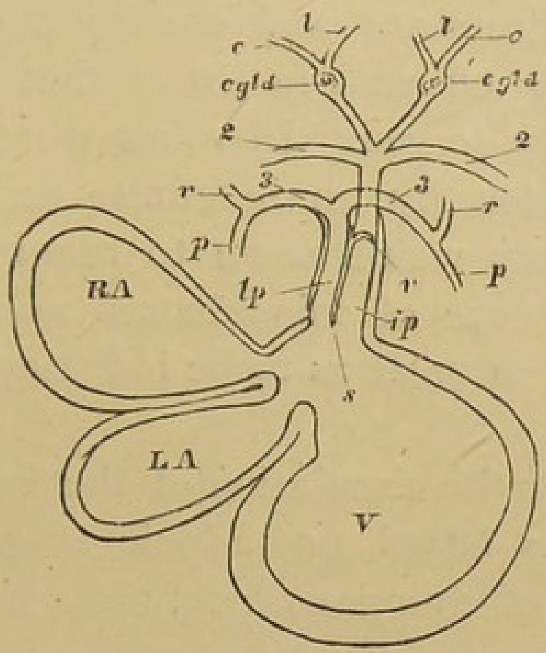

FIG. 79.—Diagram of section of Frog's Heart. *LA*, left auricle; *RA*, right auricle; *V*, ventricle; *s*, moveable septum dividing the left aortic passage *lp* from the right aortic passage *ip*; *v*, valve; 3, 3, aortic trunks leading to *p*, pulmonary artery, and *r*, cutaneous respiratory artery; 2, 2, aortic trunks going to form the great dorsal aorta; *cgld*, carotid gland interrupting the flow of blood into *l*, the lingual artery, and *c*, the carotid artery.

As the lungs get gorged with blood, the resistance on the two sides of the septum of the bulb becomes at first equalised and soon becomes the greater on the left side; then the septum is forced over to the left, and the blood, now mixed with pure blood, flowing in from the left auricle, flows freely along the systematic arteries (2 and 2). The obstruction of the carotid glands (*c gld*) being the greatest and the last to be overcome, the carotid and lingual arteries (*c* and *l*) receive the very last of the blood—that, namely, which coming from the left auricle is purely arterial—

and in this way oxygenated blood only is supplied to the head, sense organs, and brain.

It should be borne in mind that in order to develop this most beautiful and complex apparatus, the co-ordinate development in due proportion of these beneficial obstructions and checks must have been simultaneously effected in order that their purpose should be duly served. In other words, to account for its formation by an indefinite series of minute happy accidents would seem to require such a successive occurrence of coincidences as to become an improbability so great as to be indistinguishable from impossibility.

So much for the circulation of the frog in its adult condition. Its larval, or tadpole stage, presents us with a series of changes which, though more familiar, are not less wonderful.

In the first place, however, it may be well to describe shortly the condition of the circulation in fishes, where the purification of the blood is effected, not by means of the exposure of the blood to the action of air taken into respiratory cavities of the body, but by its subjection in little places of membrane, the gills, to the influence of air mechanically mixed up with and dissolved in the water in which those gills are bathed.

In fishes, moreover, unlike all air-breathing animals, none of the oxygenated blood is returned to the heart for propulsion, but is collected directly into the great dorsal aorta, whence it is distributed to the whole body, only being returned to the heart after such distribution, so that venous blood alone enters that organ.

This venous blood is sent out from the heart through a bulbous aorta, whence arise on each side a series of arteries which ascend the branchial arches, one on the outer side of each such arch, decreasing in size as it ascends. (Fig. 81.)

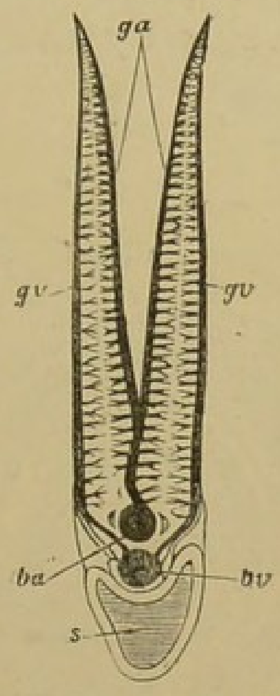

FIG. 80.—Two lamellæ (or leaflets) from the gills of an Osseous Fish, showing the course of the respiratory circulation. *s*, cut surface of one of the branchial arches. On its upper side is seen a concavity which is produced by the section of the groove which runs along the convex and exterior (here upper) side of each branchial arch. *ba*, branchial artery in section, giving off the gill arteries (*ga*) to the adjacent sides of the gill leaflets, whence the blood is distributed in the leaflets; *gv*, the gill veins which run along the outer side of the gill leaflets, collecting the blood from them by minute veins and pouring it into *bv*, the branchial vein, which runs up the groove of the branchial arch and has the branchial artery superficial and exterior to it.

Each branchial artery gives off small gill arteries, which run along one edge of each little membranous leaflet or gill, and supply it with minute branches ending in capillaries, in which the blood is purified. There the purified blood is taken up by minute veins which open into gill veins, one of which runs along the opposite edge of each gill to that occupied by the gill artery.

The gill veins pour their contents into branchial veins, one of which ascends the outer side of each branchial arch, increasing in size as it ascends. The branchial veins open into the great dorsal aorta, whence the blood is distributed over the body. Generally the branchial arteries are only connected with the branchial veins by the intervention of the

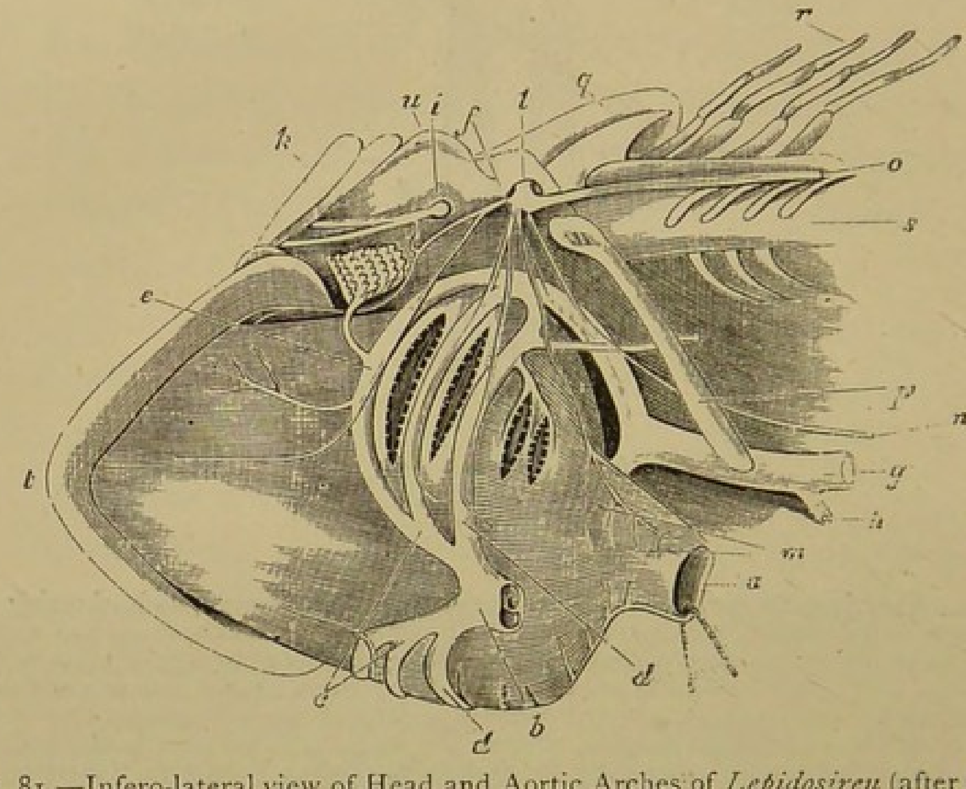

FIG. 81.—Infero-lateral view of Head and Aortic Arches of *Lepidosiren* (after Hyrtl). *a*, œsophagus; *b*, anterior end of bulbus aortæ; *c*, common roots of the first aortic arches; *d*, third aortic arch; *e*, first aortic arch; *f*, dorsal union of the first three aortic arches; *g*, aorta; *h*, cœliac artery; *i*, exit of the fifth nerve; *k*, part of operculum; *l*, exit of the nervus vagus from the skull; *m*, branches to œsophagus; *n*, nerve going to the rectus abdominis; *o*, nervus lateralis; *p*, first and hypertrophied rib; *q*, posterior part of the skull; *r*, segmented neural spines; *s*, chorda dorsalis; *t*, mandible; *u*, quadrate.

capillary vessels of the gills. Sometimes, however (as *e.g.* in the mud-fish, *Lepidosiren*) the branchial veins are directly continuous with the branchial arteries.

In the tadpole, while the gills remain fully developed, a condition exists quite similar to that of fishes. Minute vessels, however, directly connect together, at the root of each gill, the branchial artery and branchial vein of each gill. Such a connecting vessel is termed a *ductus botalli.*

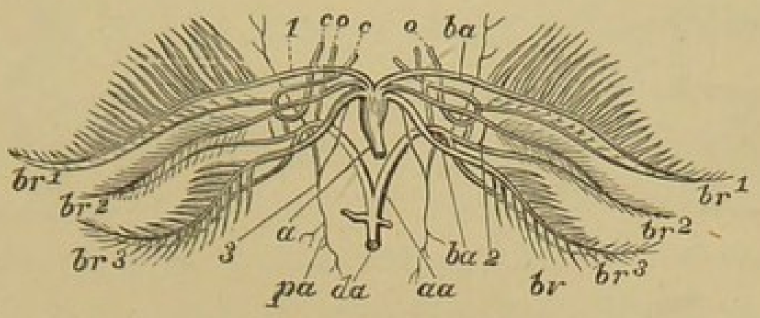

FIG. 82.—The Circulation of a Tadpole in its pr mitive stage, when nearly all the blood is distributed to the gills; the pulmonary arteries being quite rudimentary, and the vessel (or ductus botalli) connecting together the branchial artery and vein at the root of each gill being minute. *a*, bulbus aortæ; *b*, branchial arteries; br^1, br^2, br^3, the three gills (or branchiæ of each side); *bv*, the branchial veins which bring back the blood from the gills—the hindermost pair of branchial veins on each side unite to form an aortic arch (*aa*), which again unites with its fellow of the opposite side to form *da*, the descending (or dorsal) aorta. The branchial veins of the foremost gills give rise to the carotid arteries *cc*; *o*, artery going to the orbit; *pa*, pulmonary artery; 1, 2, 3, anastomosing branches connecting together the adjacent branchial arteries and veins.

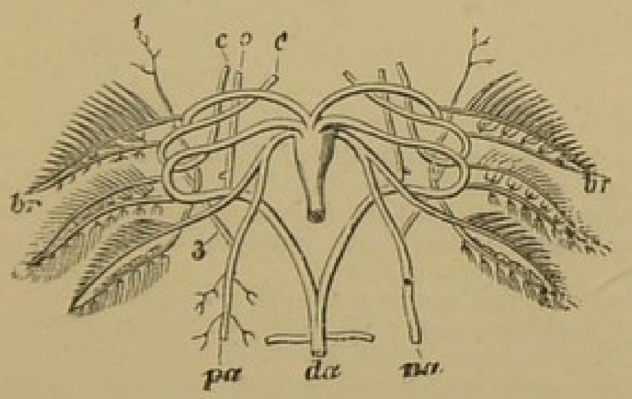

FIG. 83.

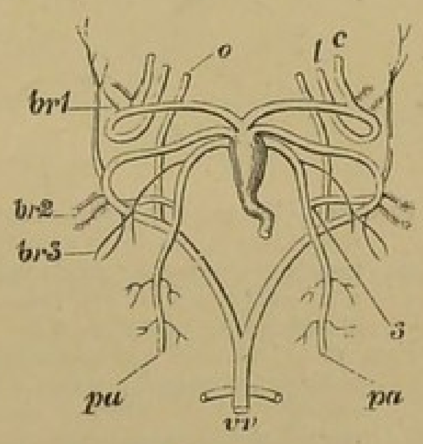

FIG. 84.

FIG. 83.—The Circulation in a Tadpole at a more advanced stage, when the gills have begun to be absorbed, the pulmonary arteries to increase, as also the connecting branches (at the root of the gills) between the branchial arteries and branchial veins.

FIG. 84.—The Circulation in a young Frog. Here the gills have been absorbed, and the blood passes directly from the heart to the head, the dorsal aorta, the lungs, and the skin.

A minute vessel given off from the third branchial artery, is the incipient pulmonary artery.

As development proceeds, as the gills diminish by

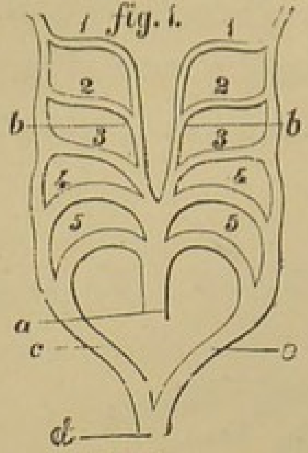

FIG. 85.

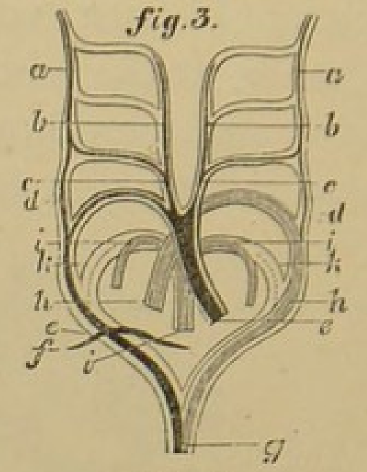

FIG. 86.

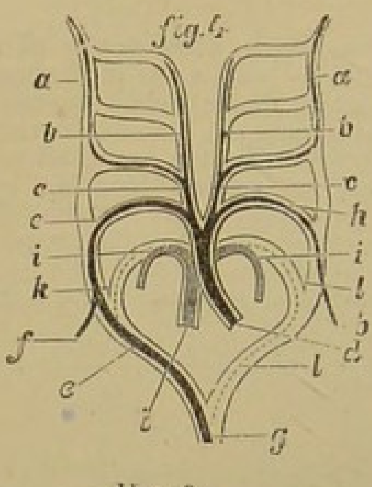

FIG. 87.

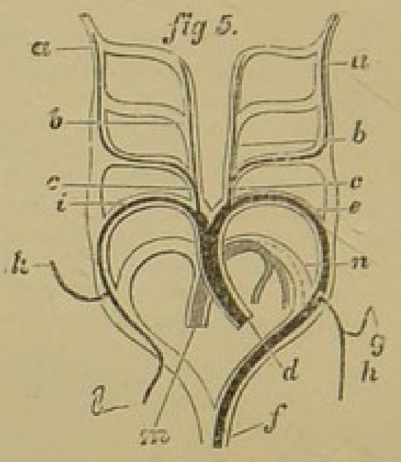

FIG. 88.

FIG. 85.—Diagram representing the primitive aortic arches of Mammals and Sauropsidans (after H. Rathke). *a*, common trunk, or root, of the aorta: *b*, *b*, the two branches into which it divides, and which give off the successive arches 1, 2, 3, 4, and 5, which end in *c*, *c*, two vessels which again unite to form *d*, the descending, or dorsal, aorta.

FIG. 86.—Diagram representing the vessels and aortic arches of a Lizard, with the changes induced on the primitive condition (after H. Rathke). *a*, *a*, internal carotids; *b*, *b*, external carotids; *c*, *c*, common carotids; *d*, *d*, anastomosis between the internal carotids and the secondary aortic arches; *e*, *e*, right main aortic arch; *f*, *f*, the subclavian arteries (which give off the vertebral, here not represented); *g*, commencement of the great dorsal aorta; *h*, *h*, left main aortic arch; *i*, *i*, *i*, pulmonary arteries; *k*, *k*, rudiments of the first (right and left) aortic arches,—Nos. 5, 5, of Fig. 85.

FIG. 87.—Diagram representing the main arteries of a Bird (fowl) with the changes induced on the primitive condition (after H. Rathke). *a*, *a*, internal carotids; *b*, *b*, external carotids; *c*, *c*, common carotids; *d*, root of main aortic arch (here right); *e*, arch of the same; *f*, right subclavian (which arises from the anastomosis of the first two right primitive aortic arches); *g*, commencement of the descending aorta; *h*, *h*, left subclavian; *i*, *i*, *i*, pulmonary arteries; *k*, right, and *l*, left, rudiments of the primitive aortic arches.

FIG. 88.—Diagram representing the main arteries of a Mammal with the changes induced in the primitive condition (after H. Rathke). *a*, *b*, *c*, carotids, as before; *d*, root of main aortic arch (here left); *e*, arch of the same; *f*, commencement of descending aorta; *g*, left vertebral artery; *h*, left subclavian; *i*, right subclavian; *k*, right vertebral artery; *l*, continuation of right subclavian; *m*, pulmonary artery; *n*, remnant of left primitive aortic arch.

absorption, and as their respective arteries and veins decrease in size and importance, each *ductus botalli* increases until at last we have established the six great continuous vessels of the adult frog.

We have, then, in the life-history of the frog, a complete transition from the condition of the fish to that of a true air-breathing vertebrate, as regards its circulation. The various conditions herein referred to have, however, an important bearing on the question of the first origin of such structure.

All higher animals, even the very highest, have the great arteries when they first appear, arranged substantially as in fishes.

From the common aortic bulb five vessels ascend each side of the neck, and more or fewer of these arteries abort in different classes, the permanent adult condition being arrived at by this circuitous route.

This argument has commonly been adduced as an argument in favour of the descent of air-breathing animals from more ancient gill-bearing forms, and it is not without weight.

Nevertheless, it must be borne in mind that the primitive condition in fishes is that of direct continuity between the branchial arteries and veins such as we have seen exists permanently in *Lepidosiren*. It is only as development proceeds that each primitive continuous arch becomes broken up into an artery and a vein connected by a network of capillaries.

Now we can understand the series of unbroken arches in higher animals as the relics of ancestral vessels which divided for gill-circulation and were therefore once of extreme functional importance and utility. But how can we understand the primitive unbroken series of arches in fishes? Their utility was yet to come!

The frog when adult has, besides its skin, no breathing organs but the lungs. As has been said before, other members of the frog's class retain gills and aquatic respiration during the whole of life, as for example *Menobranchus*.

Every one kind, however, whether provided permanently with gills or not, develops lungs, and it might easily be imagined that similarly every gilled-creature which has lungs is also a Batrachian.

This, however, would be a mistake.

The Mud-fish or Lepidosiren, already referred to more than once, is furnished with both gills and lungs throughout the whole of life. On this account it has been reckoned by some naturalists to be a fish and not a Batrachian. Its fish-nature, however, has now been thoroughly established, and thus the probability of the existence of lungs within the class of fishes is also established.

But what is a lung?

A lung is a sac-like structure capable of being distended with air, supplied with venous blood direct from the heart, and sending arterial blood directly to it. Generally the whole of the blood from the lungs goes back to the heart directly, but in one Batrachian —the celebrated *Proteus*—a portion of the blood from the lungs finds its way not into the heart but into vessels of the general circulation. When there is an air-sac which does not both receive blood directly from and return it directly to the heart—*i.e.* when there is no true *pulmonary* circulation—such an air-sac (whether single or double) is termed a *swim-bladder*, and a structure of the kind is found in very many fishes. The swim-bladder of ordinary fishes neither receives blood directly from the heart by an artery like the pulmonary artery of higher animals, nor does it return blood directly to the heart.

The transition, however, from a lung to a swim-bladder is a graduated one. We have just seen that in *Proteus*, though blood is returned from the lungs direct to the heart, yet that not all the blood is so returned. On the other hand in another animal, *Ceratodus*, though blood is not brought to its air-sac directly (which is therefore a swim-bladder and not a lung), yet for all that blood is sent *from* it direct to the heart.

Ceratodus (or as it is locally called "flat-head") is a fish of Queensland, closely allied to *Lepidosiren*, and is a very noteworthy animal apart from and in addition to its peculiarly transitional structure as regards its air-sac.

It is, indeed, the last of an ancient race, a species of the same genus (known almost exclusively by its teeth), being found fossil in strata of oolitic and triassic date. It was discovered by the Hon. W. Foster, M.C.A. Mr. Gerard Krefft, F.L.S., Curator and Secretary of the Sydney Museum, first described and figured the animal in 1870[1] and at once correctly referred it to the genus *Ceratodus*, which up to that time was supposed to be entirely extinct. Its further determination was effected by

[1] See Proc. Zool. Soc. 1870, p. 22.

Dr. Gunther.[1] He has conclusively shown that *Ceratodus* and *Lepidosiren* are closely allied, and thus finally brought the latter definitively within the class of fishes, for that *Ceratodus* is a fish no one questions. It is an animal, however, of somewhat amphibious habits, as at night it leaves the brackish streams it inhabits, and wanders amongst the reeds and rushes of the adjacent flats. Vegetable substances constitute its principal food.

Ceratodus and *Lepidosiren* together afford the most remarkable evidence of the persistence of the same type of structure in the Vertebrate sub-kingdom. The group to which they both belong reaches back into the very earliest epoch, which has yet afforded us any evidence whatever of the existence of fishes; while the genus *Ceratodus* seems to have persisted unchanged from the period of the deposition of the triassic strata.

The Excretory Organs.

As has been said, it is a necessary action for every living being, whether plant or animal (in order that it may continue to live) to eliminate certain substances, the most noteworthy being carbonic acid, which is set free by the process of respiration.

The active processes of life, however, necessarily wear out, by their activity, parts containing the gas nitrogen, which enters into the composition of every animal, and especially into every part exhibiting much vital activity.

[1] See Phil. Trans. 1871, p. 511; Plates xxx. to xlii.

The elimination of nitrogenous excreta becomes, then, a very important process, and, indeed, in ourselves death soon ensues when its elimination is prevented by injury or disease. That part of the body which is especially devoted to the excretion of the nitrogenous waste of the tissues is the renal or urinary organs—the two kidneys. Richly supplied with blood, the kidneys have the power of straining off from the blood (*i.e.* secreting) nitrogenous substances, which are also in part eliminated by the skin in perspiration.

The material so strained off or secreted, is conveyed by two long tubes, the ureters, which pass down, one from each kidney, to the bladder or reservoir of the nitrogenous excretion.

In very many animals, as *e.g.* in birds, there is no bladder, but the ureters terminate in a chamber, the cloaca, which also receives the termination of those canals (the oviducts) down which the eggs pass in order to be "laid."

In no adult bird, however, nor indeed in any adult reptile, is there any closer connection between these two sets of canals—the ureters and oviducts—which terminate independently in the cloaca. In all such animals, however, and in beasts also, at an early stage of existence we do find a certain connection between renal ducts and the oviducts or their analogues. This coincidence is owing to the fact that in such higher animals the urinary gland which ultimately exists in the adult—namely, the kidney—is not that which primitively exists, but is a subsequent formation. The primitive renal duct is not the ureter. The primitive urinary gland is what is called the "Wolffian body," which after a time ceases to grow, and ultimately more or less disappears, becoming an appendage to the glandular structure related to the oviduct or to its analogue in the other sex. Thus, though the kidney, with its duct the ureter, never has any direct connection with the oviduct or its appendages, nevertheless, a renal structure, with its excretory duct, has such a connection at one time of life, even in the highest animals.

In fishes the primitive renal (or urinary) organ persists throughout life. It answers rather to the temporary Wolffian body than to the true kidney of higher animals. It is also a fact that in some fishes (*e.g. Ceratodus* and *Lepidosiren*) a connection does exist between the renal ducts and the oviducts, anterior to the termination of either.

Now in the frog (and in its class-fellows) this highly important excretory organ presents a noteworthy condition. In the adult frogs and toads the renal or urinary gland pours its secretion by minute canals into the renal duct. This duct, however, does not open into the cloaca, as does the ureter of birds and reptiles, but into the oviduct, the oviduct and renal duct of each side thus opening into the cloaca by a single and common aperture. An analogous condition exists in the male frog and toad, and in most members of their order.

In the genera *Bombinator* and *Diseoglossus*, however, as also in the male *Urodela*, a still more intimate union exists between the renal organs and those devoted to functions complementary to oviposition. The animals just mentioned, when fully adult, unlike all higher animals, have no separate duct in the male analogous to the oviduct of the female. There is but a single tubular canal, and into it directly open minute tubes, which proceed both from the renal, or urinary, gland and from that which is the analogue of (and is complementary to) the ovary.

The interest of these conditions is twofold. In the first place, their existence is a point of affinity with fishes, since we find in those belonging to the order to which *Lepidosiren* and *Ceratodus* pertain, a similar connection between the same two sets of organs.

It is interesting, in the second place, because, though nothing of the kind exists in adult animals of a higher class than Batrachians, yet, as already stated, in the earlier stages in the development of such animals (even the very highest) we *do* find a certain analogy.

The primitive urinary gland—the Wolffian body—seems then to answer to the permanent urinary gland of Batrachians. This, together with its duct, is at first, indeed, entirely devoted to the excretory function. But, as we have seen, it ultimately more or less aborts in the adults of both sexes, and becomes an appendage, exclusively, of parts which are related directly or indirectly to oviposition.

CHAPTER X.

SUMMARY.

TAKING a rapid retrospect of the course we have pursued, we find that in seeking to decide as to "What is a Frog?" our inquiry into its absolute structure has made known to us an animal of peculiarly specialised and perfect organization. This has been shown to us pre-eminently by the study of its skeleton. We have especially noted its skull, its wonderfully short vertebral column, its utterly anomalous pelvis, and its scarcely less anomalous foot. The flesh which clothes that skeleton has been seen to exhibit distinct muscles wonderfully like our own, those of the foot, indeed, exceeding ours in number, and being a very marvel of complexity. We have met with a nervous system ministered to by delicate organs of sense, and noted for the ready response to stimuli, made by even separated parts of it, as evidenced by strikingly co-ordinated complex movements. We have found the circulation to be carried on by a heart which, at first sight, seems too structurally imperfect to distribute the venous and arterial blood in their respectively appropriate channels. Nevertheless, further examination has shown us that this heart is provided with a special arrangement of parts so delicately co-adjusted as to be able to act thus as efficaciously as does the heart of animals much higher in the scale. Respiration, too, we have seen provided for partly by an effective throat air-pump, partly by a peculiar activity of the cutaneous structures.

We have, moreover, found that this complex adult condition is arrived at by means of a rapid metamorphosis from an immature condition wonderfully different, indeed, but no less perfectly adapted to the life conditions of the tadpole state.

It remains now "to sum up the results" of our investigations through "a series of wider and wider comparisons" to answer, finally, as far as may be, the initial question of this little treatise.

We have, in the first place, seen that the frog belongs to an order far more distinct from cognate ordinal groups than is man's order from other orders of his class—mammalia. We have also seen that the frog belongs to an order which is singularly homogeneous, and yet that the class which includes it is remarkably heterogeneous.

Again, we have found that the subordinate groups of the frog's order, families and genera, have very definite relations to *space,* and that the order, as a whole, is, as far as yet known, remarkably restricted as regards geological *time.*

The comparisons instituted in our survey of the frog's anatomy, will enable us now to sum up resemblances; first, as regards the orders of its class, and secondly, as regards the class itself.

1. Its own order, *Anoura*, has been seen to present singular resemblances to the *Chelonia* amongst reptiles. Such are the bony plates of the back in some forms, the bony covering of the temporal fossa in others, the mode of inspiration in the adult, the armature of the jaws in the young. In contrast with this the peculiar elongated tarsus has reminded us of certain mammals, and the median Eustachian opening of *Pipa* and *Dactylethra* has suggested an affinity to crocodiles and birds. It has been plain, however, that these several likenesses, however singular and striking, are not evidences of genetic affinity.

2. The order *Urodela* may well recall to mind the *Lacertilia* amongst reptiles, with which animals the *Urodela* were actually classed by Linneus. Moreover in both groups we find a series of different species, longer and longer in body and shorter and shorter in limb. We have also seen that in both these groups an analogous complication obtains in the muscles of the legs.

3. The order *Ophiomorpha*, as has been before observed, present a general resemblance to serpents, and a special resemblance to certain short-tailed ones; though it is rather with the Amphisbenian Saurians that they may most advantageously be compared. Here again, however, we meet with the resemblances which, though striking, do not allow themselves to be interpreted as indices of any special relationship by descent.

4. The order *Labyrinthodonta* recalls to mind, as

has been said earlier, the Crocodilia amongst reptiles, of which they may be deemed as the prophetic precursors, so to speak, though certainly not the direct ancestors.

Thus the class *Batrachia*, as a whole, presents a very interesting analogy and parallelism with the class *Reptilia*.

It is a parallelism, moreover, which reminds us of that which exists between the various orders of Placental mammals and the great subdivisions of the pouched or Marsupial order of mammals. We have carnivorous, insectivorous, arboreal, aquatic, herbivorous, marsupial beasts, as we have carnivorous, insectivorous, arboreal, aquatic and herbivorous placental beasts. The harmonious variations of the placental and marsupial groups thus present us with excellent instances of affinities independently evolved and not due to hereditary influence.

In a similar way it seems probable that the subdivisions (orders) of the class Batrachia, mimic, as it were, quite independently the subdivisions (orders) of the class Reptilia.

The Frogs' class, as a whole, shows as many striking affinities to some or other fishes. It does so in the possession of gills and of a branchial apparatus during one time of life at the least; a large parasphenoid in the skull; the often persistently unsegmented terminal part of the notochord; the single ventricular cavity of the heart; the presence of a *bulbus aortæ*; the development of a *nervus lateralis*; the communication between the urinary canal and the oviduct, and certain other characters of less importance.

The class *Batrachia* agrees both with fishes and reptiles in having the blood cold, more than one aortic arch, and (except in crocodiles) in not having the distinct ventricles.

The class agrees with fishes, reptiles, and birds, in having no complete diaphragm, and no corpus callosum [1] in the brain, and no single aorta arching over the left bronchus.

We have now arrived at the end of those considerations seemingly best suited to enable us to answer the initial question, "What is a Frog?" The requisite definition might, of course, have been given much earlier, but these inquiries have seemed necessary to enable the reader to understand the technical terms of such definition—to give them, in his eyes, a real meaning.

The Frog is a tailless, lung-breathing, branchiate vertebrate, with four limbs typically differentiated, undergoing a complete metamorphosis, and provided with teeth along the margins of the upper jaw.

If further exposition be necessary, it may perhaps now be most conveniently effected by means of a series of statements respecting the anatomical differences existing between the frog and other groups of vertebrate animals.

The frogs differ from toads in that the former have marginal upper teeth.

They differ from other Batrachians in that there are four limbs, while the tail is absent.

[1] As to this structure see Lesson in "Elementary Anatomy," pp. 367, 375.

Outside the Frogs' own class, the differences may be tabulated as follows :—

The FROG differs from the entire class of FISHES in the following points :—

1. It has a skeleton, the appendicular parts of which are divided into upper arm, fore-arm and hand, and thigh, leg, and foot, respectively.
2. Its hyoid, when adult, has but one pair of cornua instead of several branchial arches.
3. Its skull is bony, yet devoid of a basi-occipital bone.
4. It has a pelvis formed of ilia, ischia, and pubes.
5. Its coccygeal region is rudimentary.
6. Its skin is devoid of scales.
7. Its limb-muscles are numerous and complex.
8. Its nostrils open posteriorly within the mouth.
9. The ear is provided with Eustachian tubes.
10. The tongue is large, fleshy, and free behind.
11. The adult is devoid of gills.
12. It has a larynx.
13. It has lungs with a pulmonary circulation.
14. It has no fin rays.
15. It has no tail—in the adult.

The FROG differs from all REPTILES in that—

1. The skull has no basi-occipital bone, while it at the same time has a large paraphenoid.
2. There are two occipital condyles.
3. Two of the tarsal bones are greatly elongated.

4. The acetabula are closely applied, and that there is an iliac symphysis.
5. The bones of the fore-arm and those of the leg are anchylosed together respectively.
6. There is no distinct atlas vertebra.
7. The coccygeal region is formed by ossification of the sheath of the notochord.
8. There is no femoro-caudal muscle even in the young—when the tail is long.
9. The tongue is free behind.
10. The skin is devoid of horny scales.
11. Development takes place through a metamorphosis.
12. Gills exist in the young.
13. The ureters open into the oviducts.

The FROG differs from all BIRDS in that—

1. Its blood is cold.
2. The skull has no basi-occipital.
3. It has two occipital condyles.
4. It has a large paraphenoid.
5. It is provided with teeth.
6. The hand has four fingers.
7. The foot has five toes.
8. The iliac bones articulate with but one vertebra.
9. There is an iliac symphysis and the acetabula are closely applied together.
10. The fore-arm bones are anchylosed together.
11. The leg bones are anchylosed together.
12. Two of the tarsal bones are greatly elongated.
13. There is no distinct atlas vertebra.

14. There are no neck vertebræ.
15. No ribs join the sternum.
16. There are no feathers or scales.
17. There is no beak in the adult.
18. There is no second (and inferior) larynx.
19. There are not two ventricles to the heart.
20. There is more than one aortic arch.
21. The optic lobes are not lateral and depressed.
22. The tongue is free behind.
23. Development takes place through a metamorphosis.
24. Gills exist in the young.
25. The ureters open into the oviducts.

The FROG differs from the MAMMALS in that—

1. Its blood is cold.
2. The skull has no basi-occipital.
3. It has a large paraphenoid.
4. There is an iliac symphysis.
5. The acetabula are closely applied together.
6. The coccygeal region is formed by ossification of the sheath of the notochord.
7. The tongue is free behind.
8. The skin is devoid of hair.
9. There is no distinct atlas vertebra.
10. There are no neck vertebræ.
11. No ribs join the sternum.
12. There are not two ventricles to the heart.
13. There is more than one aortic arch.
14. There is no muscular partition between the chest and abdomen, *i.e.* no diaphragm.

15. Respiration takes place through the introduction of air by an action of swallowing.
16. Development takes place through a metamorphosis.
17. Gills exist in the young.
18. There is no corpus callosum.
19 The ureters open into the oviducts.

The course of our inquiry into the nature and affinities of the Frog has not alone served to answer the question with which this memoir opened. Incidental bearings upon deep biological problems have come before us more than once in its course, nor have all the conclusions which seem to have forced themselves upon us been totally negative.

Thus we have met with several instances of the independent origin of remarkably similar structures, such as a shielded temporal fossa and elongated tarsus, which together with structures like the tooth of the Labyrinthodon, seem to be characters for the existence of which neither the destructive agencies of nature acting on minute oscillations of structure, nor any sexual phenomena will account.

Again in the life history of the Frog, considered even purely by itself, we find a remarkable example of spontaneous transformations due to innate powers and tendencies.

When, however, this process is considered in the light derived from the curious phenomena of transformation so enigmatically presented to us by the axolotl, we have very strongly brought before us the powerful action of internal tendencies lying dormant and latent till made manifest, through the advent of conditions so obscure that as yet they have evaded the most careful and anxious scrutiny of practised adepts.

It would seem to be a negligence not here to point out, that if new forms of life—new species—arise from time to time through congenital variation, not a few of the facts herein quoted point to the probability that such forms have arisen through the evolutions of implanted potentialities definite in nature, in other words, by "specific genesis."

Again, a general survey of the different kinds of relations which the Frog has brought before us is well calculated to impress us with the overwhelming richness and fulness of nature.

Although, from our ignorance, the natural history of many other animals well known to us may appear less replete with interest than that of the common Frog may now be, yet it cannot be doubted but that the progress of science is capable of revealing to us facts as full of instruction, and of as profound a significance in the life history of almost any kind of animal whatever.

Ever fresh, ever fertile, natural history offers to our faculties a pursuit practically inexhaustible. We are not, indeed, denied the gratification of successfully exploring and satisfactorily explaining mystery after mystery, but each secret wrested by our efforts brings before us other ever-new enigmas, so that though refreshed by success we need never be wearied by monotony. While we need not regard any problem as absolutely hopeless, no dread of coming to the end of our inquiries need ever chill the warmth of our zeal in the scientific cause. Some may consider such reflections justified by the phenomena presented to them by the natural history of the Common Frog.

THE END.

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