LESSONS

IN

ELEMENTARY ANATOMY.

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BY

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London:
MACMILLAN AND CO.
1873.

LONDON:
R. CLAY, SONS, AND TAYLOR, PRINTERS,
BREAD STREET HILL.

PREFACE.

THE following "Lessons in Elementary Anatomy" are intended in the first place for teachers and for earnest students of both sexes, not already acquainted with human anatomy.

I have endeavoured, secondly, by certain additions and by the mode of treatment, to fit them for students in medicine and generally for those acquainted with human anatomy, but desirous of learning its more significant relations to the structures of other animals.

My hope is that this little volume may thus serve as a handbook of Human Morphology.

Man has been selected as the type, because his structure has been the most studied and is the most intimately known, as also because our own frame is naturally the most interesting to ourselves. But this book has no pretension to be a "Comparative Anatomy." It does not profess to give a complete account of the anatomy of any group of animals. It contains but a selection of facts intended to illustrate the variations which nature shows in that type of structure to which man's body belongs.

So far as I am aware, this endeavour is the first of its special kind, and I have felt much difficulty as to the facts to be selected, fearing on the one hand to overload an elemen-

Each order consists of smaller groups, which groups bear each the title *family*.

Each family is composed of still smaller divisions, termed *genera*.

Each genus is made up of one, few or many *species;* each species being composed of individuals differing only as regards sex, and capable of reproducing other individuals similar to themselves.

The whole of these groups are defined by peculiarities of form and structure; that is to say, the classification is based upon the number and shape of parts and organs, and not by what such parts and organs do, *i.e.* it is morphological and not physiological.

9. One great primary group, *i.e.* one sub-kingdom (or division)—that to which we belong—includes, besides ourselves, all beasts, birds, reptiles, frogs, toads, and efts (or newts), and all fishes truly so called. The creatures of this sub-kingdom agree in possessing a spine, that is a backbone (or a cartilaginous or gelatinous representative of it). In all the higher of these animals, including man, the backbone is made up of a number of bony pieces termed vertebræ, and on this account the term VERTEBRATA is given to the whole group, which is spoken of as the Vertebrate sub-kingdom.

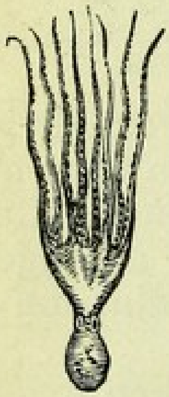

FIG. 2.—A POULPE CUTTLE-FISH (*Octopus*).

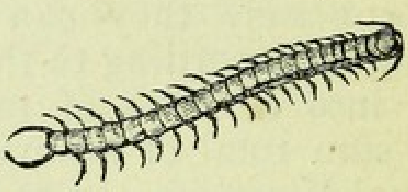

FIG. 3.—A CENTIPEDE, OR HUNDRED-LEGS (*Scolopendra*).

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made up of a longitudinal series of more or less distinctly traceable segments or rings, at least at some period of their lives. Such creatures are all insects, crabs, lobsters, shrimps,[1] scorpions, spiders, hundred-legs, earth-worms, and leeches. This sub-division is the richest in numbers of the whole animal kingdom; and even one class of it, *Insecta* (which comprises all insects), contains so many species as to exceed in number all other species of animals put together.

A fourth sub-kingdom is made up of creatures less familiar to many, namely, sea-squirts or ascidians,[2] lamp-shells, and

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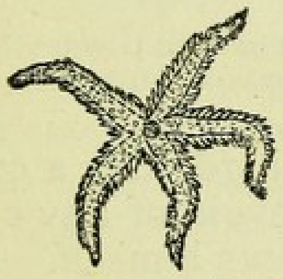

FIG. 5.—A STAR-FISH (*Uraster*).

FIG. 6.—A TUBULARIAN POLYP (*Bimeria*), after Allman.

minute animals living in compound aggregations, often found on our shores, such as the *flustra*, or sea-mat. To this sub-kingdom the name MOLLUSCOIDA[3] has been applied.

A fifth sub-kingdom is composed of animals like star-fishes, sea-urchins, and sea-cucumbers, together with entozoa,[4] or intestinal parasites and their allies, on all of which the common name ANNULOIDA[5] has been imposed.

A sixth primary group bears the title CŒLENTERATA,[6] and contains all sea-anemones, jelly-fishes, Portuguese men-of-war,

[1] Crabs, lobsters, and shrimps are sometimes improperly spoken of as shell-*fishes*.

[2] From ἀσκός, a wine-skin or pouch.

[3] Molluscoida, from mollusca and εἶδος, form, appearance.

[4] Ἐντός, in, and ζῶον, animal.

[5] Annuloida, from *annulus* and εἶδος.

[6] Cœlenterata, from κοῖλα, hollow; ἔντερα, entrails.

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LESSON I.

A GENERAL VIEW OF THE STRUCTURE OF THE HUMAN BODY AND ITS RELATIONS TO OTHER ANIMAL BODIES.

1. No object can be understood by itself. We comprehend any thing the better the more we know of other things distinct from, but related to it.

"You understand a particular kind of animated being, when looking inwards you see how its parts constitute a system, and again looking outwards and around, how this system stands with regard to other types of organized existence."[1]

Man is an animal, and feels—in other words, forms one of a multitude of different kinds of organized and sentient beings, the bodies of which have obvious, but very various, relations with his body. It is clear, then, from the nature of the case that man's body can only be comprehended by means of an extensive acquaintance with the bodies of other animals.

Experience confirms this conclusion: as the exclusive study of man's body, though sufficient for the mere art of the surgeon, has led to quite erroneous estimates of the nature and meaning of parts of it; errors corrected only through

[1] Essays by James Martineau; Second Series, p. 417.

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the general science of organic forms, *i.e.* the science of Morphology.[1]

2. The body of man has a more or less rounded outline, and its various surfaces are curved. Moreover, as everyone knows, it is made up of different parts and organs—hard and solid structures (bones) being enclosed by soft and pulpy flesh. Indeed nearly all parts of man's body contain much water: thus even 70 per cent. of the human brain is composed of that fluid.

As to chemical composition, most ingredients of the human body (unlike the fat) contain nitrogen; while a peculiar organic substance termed *protein*[2] (formed of the gases oxygen, hydrogen, nitrogen, and of the solid element carbon) constitutes its basis and foundation.

3. Man's body is evidently divisible into head, trunk, and limbs.

Certain symmetrical relations and contrasts between different parts of the human frame are obvious.

Thus there is a contrast between its anterior and its hinder aspect, and this contrast extends along each limb to the ends of the fingers and toes. The hinder aspect in all cases is termed "dorsal," the anterior one "ventral," and, indeed, we familiarly speak of the *back* of the hand.

Again, there is a resemblance (and at the same time a contrast) between the right and left sides, which correspond with tolerable exactitude one to the other. This harmony, termed *bilateral* symmetry, though obvious externally, does not in man extend to the internal organs (or viscera), which are more or less unsymmetrically disposed.

Thirdly, there is a resemblance and correspondence between parts placed successively, as, for example, between the arm and the leg, or between the hand and the foot; although this relation is less obvious than it might be, owing to the different directions in which the knee and elbow are bent. Such a symmetry is termed *serial*, and is thus externally visible; but it is more manifest on a deeper examination, where we find successive parts like the ribs or the pieces of the backbone, which obviously resemble each other more or less, and so are called by a common name, while as they are placed in "series" they are excellent examples of *serial symmetry*.

4. As is familiar to all, man's body consists of a solid frame-

[1] Morphology, from the Greek words μόρφη, form, and λόγος, discourse.

[2] Protein, from πρῶτος, first; πρωτεύειν, to be the first; πρωτεῖον, the first place; because it holds the first place in relation to the albuminous principles.

work (the bony skeleton), on which are laid bundles and layers of flesh or muscle, the whole being enclosed by skin.

An external opening, the mouth, is the beginning of a long and convoluted alimentary tube, which varies in size in different parts before reaching its termination, and has annexed to it a variety of glands, as the liver, pancreas, and salivary glands. This long tube occupies part of a great internal cavity in the trunk of the body, in which cavity are also placed the heart, lungs, spleen, kidneys, and bladder, the heart[1] being situated on the ventral aspect of the cavity.

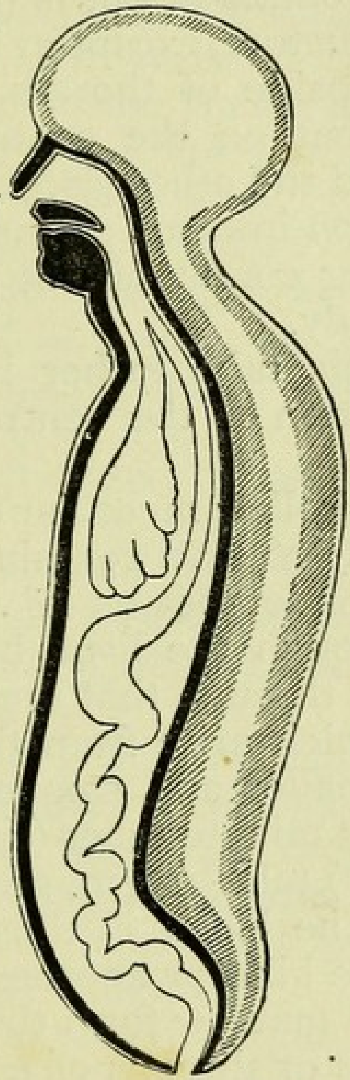

FIG. 1.—A DIAGRAMMATIC SECTION OF THE HUMAN BODY TAKEN VERTICALLY THROUGH THE MEDIAN PLANE.

The ventral cylinder, containing the convoluted alimentary tube, lungs, &c., is bounded by the thick black line.

The dorsal cylinder, bounded by oblique lines, is shown expanding above into the brain cavity.

5. Thus man's trunk may be conceived as a sort of fleshy cylinder, but in fact it is made up of two cylinders of very different size and structure.

[1] The various organs here enumerated by anticipation are described in subsequent Lessons.

The second, and much smaller cylinder, runs along the back, and consists of the backbone, expanding above into the skull (or brain-case). This cylinder contains the spinal marrow, while its upper expansion contains the brain. The trunk of the human body consists thus of two tubes, with a solid partition between them formed of the front part of the backbone. Neither of these cavities is prolonged into the limbs, which are made up of solid structures (flesh, nerves, and vessels) wrapped round bones.

6. The long alimentary tube has no communication with the body-cavity which surrounds it, but is (with its glandular adjuncts) a continuous structure, except at its terminal openings.

Thus it is not the inside of the alimentary tube which is the *true* body-cavity, but, on the contrary, the space which surrounds that tube and the other viscera. The tube itself is, as it were, but a reflexion inwards of the external surface, the skin which lines it being continuous at the lips with the skin of the outside of the body.

At its upper end this tube rather bends away from the brain or upper termination of the central part of the nervous system.

The heart, which is a hollow muscular organ, is rhythmically contractible and propulsive, and contains red blood; part of which, as it circulates, undergoes on its way back a subsidiary (portal) circulation through the liver, by means of a double set of vessels ramifying through that organ.

The blood-vessels which arise from the heart (*i.e.* arteries) become successively smaller and smaller as they pass away from it, and end in most minute tubes (capillaries), whence the returning vessels (veins) take origin, growing larger as they approach the heart. The blood is thus constantly enclosed in distinct vessels of one kind or another.

The brain and spinal marrow form the central parts of the nervous system. Cords or threads of nervous substance (the nerves) extend from the brain and spinal marrow into every part of the body.

The lungs (as has been shown in "Elementary Physiology," Lesson IV.) respire air, but man has not any appliance by which to extract oxygen from air as it exists mixed up in water, whether fresh or salt.

The sense organs, except touch, are all placed in the head, and the respiratory organs open at the same part of the body, namely, by the nose and mouth. Three special senses are furnished with pairs of organs—two eyes, two ears, two nostrils.

The mouth is bounded by jaws which open vertically, the aperture itself being extended transversely.

7. Such being the more significant and general characters of adult man, certain processes and changes of growth may be referred to by which that condition is arrived at.

A minute rounded, almost structureless mass is the earliest condition of the body.

The first indication of the future being, which shows itself in that rounded mass, is given by a longitudinal groove marking the place of the spinal marrow and brain.

Beneath this a similarly longitudinal, cellular rod appears, called the notochord,[1] or *chorda dorsalis*, marking the place of the future front part of the backbone.

In process of time the lower jaw appears as a solid rod coming down on each side from the head, and a series of similar structures, called "*visceral arches*," make their appearance on each side, also coming down from the head like the lower jaw, and placed one after the other behind (or, if the body is vertically placed, beneath) that jaw, and forming later the tongue-bone, &c.

These arches are separated by temporary apertures termed "*visceral clefts*."

8. The world is inhabited by a vast animal population, of kinds so numerous and diverse that the study of them would be a task of hopeless difficulty were they not capable of convenient classification.

Fortunately they can be and have been divided and arranged, according to their resemblances in form and structure, into a series of more and more subordinate groups. The sum total of animals is spoken of as a kingdom—the Animal Kingdom—in contrast with and distinction from the Vegetable and Mineral Kingdoms.

The Animal and Vegetable Kingdoms taken together constitute the "organic world," and each member of it is an "organism."

The Animal Kingdom is made up of certain great primary groups, each of which is termed a sub-kingdom (or sometimes a division).

Each sub-kingdom is made up of and is divisible into certain other subordinate (yet still great) groups, each of which is called a *class*.

Each class is composed of a certain number of more subordinate divisions, each of which is termed an *order*.

[1] Νῶτος, back, and χορδή, chord.

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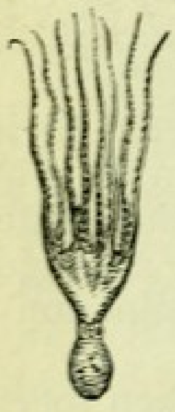

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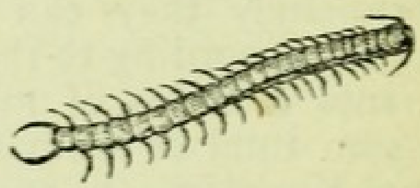

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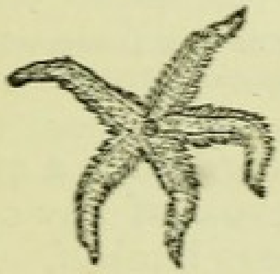

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&c., and all polyps, including many compound animals which grow up in a tree-like manner, and the minute creatures which by their secular existence have formed not only such parts of the earth's surface as reefs and coral islands, but even the State of Florida itself, of which they were undoubtedly the first founders.

Lastly, we have the sub-kingdom PROTOZOA,[1] containing all the lowest forms of animal life, placed together rather owing to the absence in them of characters possessed by higher groups than from positive characters which they share in common.

Such are the Infusoria,[2] the sponges, and those wonderful Foraminifera[3] which took (and are taking at the bottom of the Atlantic) so large a part in the formation of the chalk, and therefore built up much of Old England itself.

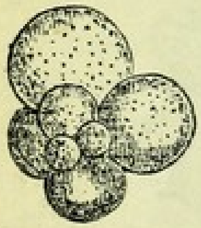

FIG. 7.—A FORAMINIFER (*Globigerina*).

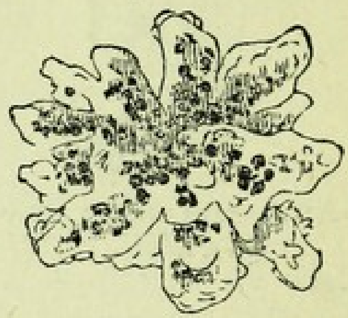

FIG. 8.—ONE OF THE LOWEST PROTOZOA (*Protomœba*), after Haeckel.

In the lowest grade of the animal kingdom is a creature, *Protogenes*,[4] at once structureless and devoid of any constant form, as its shape varies like that of Proteus himself. A mere morsel of semi-fluid jelly, floating in the ocean, it is destitute of any organ, even so much as a cell, and exhibits animality in the last degree of structureless simplicity.

The last six sub-kingdoms may very conveniently be taken together, and spoken of as the *Invertebrata*, in contrast to the highest sub-kingdom, from which in so many points the other primary groups agree in differing. Thus we have the Vertebrata on the one hand, and on the other the Invertebrata, including the Mollusca, Annulosa, Molluscoida, Annuloida, Cœlenterata, and Protozoa.

11. Having made this rapid survey of the whole animal kingdom, it will be well to consider the general characters

[1] Protozoa, from πρῶτος, first ; ζῶον, animal.
[2] So called because found in infusions when left exposed to the air for a time.
[3] *Foramina* and *fero*, having holes or perforations.
[4] Πρῶτος, first ; γίνεσθαι, to be born.

of man's structure, already noted, in relation to the other forms of life here enumerated.

In that man's body is bounded by curved lines and surfaces, and its structure complex, so that upon a section being made it is seen to consist of different parts—it agrees with those of all other animals, as even in *Protogenes* there are granules. Thus it differs from inorganic substances, which may be, as in crystals, bounded by right lines, flat surfaces, and have a homogeneous section—a cut crystal being the same in structure throughout. Only very rarely (as in spathic iron and dolomite) are minerals bounded by curved lines and surfaces.

The presence of much water is also a common character of organic living bodies, though man may be called solid in comparison with some animals, more than 99 per cent. of water entering into the total composition of a jelly-fish.

As to his chemical composition, man agrees with the whole animal kingdom, and differs from the members of the vegetable kingdom in the less proportion of non-nitrogenous parts which help to compose his body.

12. In so far as man's body is furnished with a distinct head, he agrees not only with other vertebrates (with one exception—the lancelet, or *Amphioxus*), but also with the higher Mollusca and Annulosa. It is a character, however, quite wanting in the lower sub-kingdoms, and even so well-organized an animal as the oyster is quite destitute of any such part.

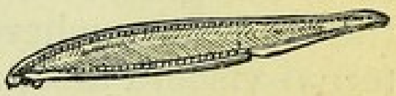

FIG. 9.—THE LANCELET (*Amphioxus*).

The presence of limbs is not a universal character even in man's own primary division, the Vertebrata, being wanting, *e.g.*, in serpents; but the possession of more than four is known only in the Annulosa, where, however, the number may be not merely six, as in insects, but prodigious, as in the millepedes, or thousand-legs.

13. The contrast between dorsal and ventral structures is one very widely shared, but is absent in the lowest animals—which thus remind us of that earliest condition of man before referred to, when his body is a minute spheroidal mass.

A dorsal and ventral symmetry may be developed such as man does not exhibit, and this is especially the case in the region of the tail, where (as, *e.g.*, in fishes and amphibians) the structures on the dorsal side of the centre of the backbone tend to be repeated on its ventral side.

The continuity of the dorsal and ventral surfaces of the limbs with the dorsal and ventral surfaces of the body, as also the correspondence between the dorsal (and ventral) surfaces of the two pairs of limbs, may be more plainly exhibited than in man. Thus in many tortoises both the knee and the elbow are rather turned outwards, than the former forwards and the latter backwards, as is also the case in the Flying-Lemur (*Galeopithecus*) amongst beasts.

FIG. 10.—THE FLYING-LEMUR (*Galeopithecus*).

Bilateral symmetry is common to man and the majority of animals. It may, however, be much less complete than in him, as in the flat fishes (such as the sole, turbot, flounder, &c.), where both the eyes come to be on one side of the head; and it may be wanting altogether, not only as regards the viscera, but also as regards the external form, as is the case in many Mollusks, *e.g.* the snail.

On the other hand, this kind of symmetry may be carried to a far greater extent than it is in man, as is the case in the Annulosa, where not only the external form, but the internal viscera also, are bilaterally symmetrical.

An *antero-posterior symmetry* may be developed to a certain superficial extent, as in the reptile *Amphisbena*,[1] in which it is at the first glance difficult to tell the head from the tail.

FIG. 11.—A STAR FISH (*Uraster*).

Another form of symmetry which is entirely absent in man is *radial symmetry*. This symmetry is exhibited by jelly-fishes and by sea-urchins, and star-fishes in their adult condition—parts radiating from a common centre resembling and corresponding one with each other.

Serial symmetry may be much less and much more developed than we find it to be in man. Thus, in such creatures as the oyster it is completely absent. In birds it is less marked than in man, the dissemblances between their wings and legs being more obvious, and the resemblances more hidden, than between the human upper and lower limbs. In contrast with this we find in forms closely allied to man the resemblance to be exaggerated—whence the name Quad-

[1] From ἀμφίς, for ἀμφί, on both sides, and βαίνειν, to go.

rumana has inexactly been applied to the apes, the foot having so close a superficial resemblance to the hand. Parts which answer to each other in serial symmetry are termed "*homotypes*."

An amount of serial symmetry, however, far beyond anything which man presents is developed in the sub-kingdom Annulosa, as we may see in such creatures as the lobster. Not only is there in such animals an obvious serial repetition in similar segments and similarly formed limbs, but a little study shows that parts superficially unlike (as the feelers, or antennæ, jaws, claws, legs, and swimmerets) are essentially similar structures, diversely modified to meet diverse requirements.

The maximum of serial repetition, however, is found in the hundred-legs and thousand-legs and other Annulosa, in which the number of body segments is at its maximum.

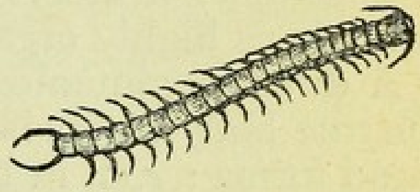

FIG. 12.—A CENTIPEDE, OR HUNDRED-LEGS (*Scolopendra*).

14. The possession of a solid internal frame-work to which muscles are attached is a character man shares with all the members of the Vertebrate sub-kingdom; but quite other conditions may obtain and indeed numerically preponderate, as in the vast group of Annulose animals, where the hard parts are external, and the muscles which move them are within them and attached to their inner surfaces, as familiarly known to us in the lobster.

15. A permanent mouth may seem to many to be an organ necessary to every animal. This, however, is not the case, as animals so complexly organized as the tapeworm are altogether destitute of any such structure and feed by absorption only. Even certain minute creatures which swim freely about to seek their food may yet have no permanent mouths, but (as, e.g., *Amœba* and *Protogenes*) when in contact with their food may produce a temporary perforation in the surface of their own body in which they engulph their food, the body-wall closing up again over it.

It becomes, then, hardly necessary to say that an alimentary tube is not a constant structure, still less any inferior outlet; for many animals, *e.g.* the lamp-shell (*Terebratula*), though possessing an intestine, are nevertheless aproctous.[1]

The various organs which aid digestion disappear as we

[1] From α, not, and πρωκτός, anus.

descend in the animal scale, but a liver is a structure which long persists, as *e.g.* in the Mollusca and many Annulosa.

16. In that man's body consists of a double tube—the nervous cylinder being dorsal and the heart ventral—it agrees with the whole of the members of his sub-kingdom, but appears to differ from that of all invertebrates, unless it be certain Ascidians. Recent observations show that the latter simulate in their larval condition the vertebrate structure as regards the existence of a dorsal nervous cylinder, as also as regards a solid partition or simulation of a notochord, which nevertheless is not yet unequivocally manifested, outside the Vertebrate sub-kingdom.

A prolongation of the body cavity and even of the digestive cavity into the limbs, strange as it may appear, is far from unknown, as it exists not only in the star-fishes, but also in animals as highly organized as spiders.

A direct communication between the alimentary canal and the true body-cavity is by no means uncommon in lowly organized forms ; *e.g.*, in the sea-anemone that canal terminates freely in the body-cavity.

In creatures in which the central part of the nervous system is ventral—that is to say, in all the Annulosa—the anterior part of the alimentary tube not only bends towards but traverses the nervous centres. That bending away from those centres which characterises it in man, characterises it also in all vertebrate animals.

Speaking generally, the nervous centres of invertebrates are placed in the oral region, as not only in the Annulosa and Annuloida, but also in the Mollusca and Molluscoida, it is present in that part, unless absent altogether.

17. The possession of a heart and of red blood is common to all vertebrates as well as to man, with one solitary exception : the Amphioxus or lancelet alone having colourless blood, and a simple cylindrical vessel in place of a heart.

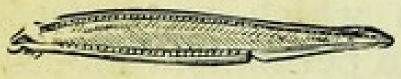

FIG. 13.—THE LANCELET (*Amphioxus*).

A portal circulation is shared with man by all vertebrates, even the Amphioxus, but no invertebrate animal is known to be furnished with a blood distribution of the kind.

Also the enclosure of the blood in vessels is a character common to vertebrates, but in Annulose animals (*e.g.* the lobster) the blood is in part contained in wide cavities termed sinuses. In many forms also (as in the Mollusca) a communication takes place between the interior of the circulating system and the exterior of the body, so that the water in which such creatures live is admitted within their blood system to a greater or less extent.

18. A distinct brain is common to all the members of man's sub-kingdom except the lancelet; but both nerves and nervous centres may be entirely wanting in creatures of complex structure like the tapeworm, or of locomotive power like the polyp, *Hydra tuba*.

Respiration of air by pulmonary sacs is neither universal in man's sub-kingdom (for fishes breathe the air contained in water by gills), nor unknown out of it. Such structures exist in scorpions and spiders, and an air-breathing sac is found in slugs and snails.

On the other hand, breathing organs suited for aquatic respiration may be developed in the most varied situations; *e.g.*, attached to the legs, as in the lobster, or internal with an external opening at the *hinder* end of the body, as in the sea-cucumber, *Holothuria*.

Kidneys, instead of being distinct structures as in man, may be united with biliary glands and open into the intestine, as in insects.

19. Sense organs may exist in quite other situations than those in which they are placed in man. Eyes may be placed on every joint of a long body, as in the worm-like animal, *Polyophthalmus*,[1] or along each half of a fleshy cloak enclosing the body, as in *Pecten*. There may often be more than two upon the head, as in *Scorpio;* or they may be raised on solid stalks, as in the lobster; or at the end of long retractile tentacles, as in the snail.

Auditory organs may be placed in joints of the legs, as in some insects, *e.g.* locusts; or in the thoracic part of the body, as in crickets.

Long filamentary jointed structures (the antennæ of insects) may project from the head, to minister to a sense the nature of which is disputable.

The mouth, instead of being extended transversely, may be rather antero-posteriorly elongated even in man's sub-kingdom, as in the lancelet; and there may be numerous jaws placed on each side of it working laterally, and not vertically, as in the lobster.

20. Development may take place without any primitive groove and without any *chorda dorsalis*, and such is the case

[1] From πόλυς, many; ὄφθαλμος, an eye.

in the whole of the Invertebrata (as far as yet known), with the doubtful exception of Ascidians.

Visceral clefts and arches may persist throughout life, as in fishes; but with respect to this, much more will be said later.

From the foregoing concise statement of the more important general characters of man's anatomy and that of animals generally, it is evident that his frame has been constructed upon a certain plan which in its main characters is common to all the members of one large group (sub-kingdom) of animals.

This will become manifest when we proceed more into detail and discover structures the utility of which is, to say the least, apparently subordinate to their significance as conforming to a general type of structure.

21. It may well be the case that the rational faculties of man could have been united to no more suitable a body than that which he possesses. Fancy may nevertheless amuse itself by considering possibilities of structure (as shown by what we find in existing animals) were he not tied down to conformity to the vertebrate type.

The fabled Briareus is suggested by the "thousand-legs" and centipede. A natural armour, moved by a cunningly adjusted internal mechanism, is suggested by the lobster. A spear tipped with poison, like the wourari, is suggested by the wasp; and the appliances of even the most modern warfare by the Bombardier Beetle.

Eyes multitudinous, attached to movable stalks or at our fingers' ends—ears in our breast, or attached to our shin-bones—are suggested by what we know of some insects.

22. It is the fact, however, that man's body is strictly vertebrate, and vertebrate only. It remains then to consider it from the vertebrate point of view. His resemblances to all animals below the Vertebrata are so general and remote, that it would be profitless henceforth to consider and compare (in going into the details of his structure) any such distant resemblances or relationships as those presented by invertebrate animals, of which we accordingly here take leave.

It is needful, however, to have a clear general conception of the animals which compose the Vertebrate sub-kingdom, to which repeated references will henceforth be made.

23. The Vertebrata are divisible into five great classes, which stand in different degrees of relationship one to another:—I. MAMMALIA (Man and Beasts); II. AVES

(Birds); III. REPTILIA (Reptiles); IV. BATRACHIA (Amphibians);[1] V. PISCES (Fishes).

Moreover, *Aves* and *Reptilia* are classed together in a large group (or province) which bears the name SAUROPSIDA. Similarly *Batrachia* and *Pisces* are grouped together, and to their united mass the common name ICHTHYOPSIDA is applied.

The class Mammalia comprises all the creatures which suckle their young, and is made up of man together with all beasts, and each is spoken of as a mammal. All mammals are divisible into three great groups or *sub-classes.*

The first sub-class comprises man and all the more well-known beasts. It is called MONODELPHIA, and the animals contained within it are termed Monodelphous mammals.

These are arranged in the following orders :—

I. PRIMATES.—Man, the Apes of the Old and New World, together with the Lemurs. Among the Apes and Lemurs are—the Gorilla and Chimpanzee, the Orang, the Gibbons, the Proboscis Monkey, the Barbary Ape (*Inuus*), the Baboons (*Cynocephalus*), the Spider Monkeys (*Ateles*), the Howlers (*Mycetes*); also *Pithecia*, *Chrysothrix*, the Squirrel Monkey, the Marmorets (*Hapale*), and the genera *Indris*, *Lemur*, *Microcebus*, *Galago*, *Loris*, *Nycticebus*, *Tarsius*, and *Cheiromys*, or the Aye-aye.

FIG. 14.—A LONG-ARMED APE, OR GIBBON (*Hylobates*).

FIG. 15.—A LEMUROID OF THE GENUS *Lemur*.

FIG. 16.—THE AYE-AYE (*Cheiromys*).

II. CHEIROPTERA.—The Bats, including the Flying Foxes (*Pteropus*), the common bats, the Horseshoe and

[1] *E.g.* frogs, toads, efts.

Vampire bats (*Phyllostoma* and *Rhinolophus*), and the Bloodsucker (*Desmodus*).

III. INSECTIVORA.—Small insect-eating beasts, such as the Mole, the Hedgehog, the Tanrecs (*Centetes* and *Hemicentetes*), the Golden Mole (*Chrysochloris*), the Shrew-Mice (which are not at all really mice), *Sorex*, and the African jumping shrews (*Macroscelides*); also the so-called Flying-Lemur (which is not a lemur), *Galeopithecus*.

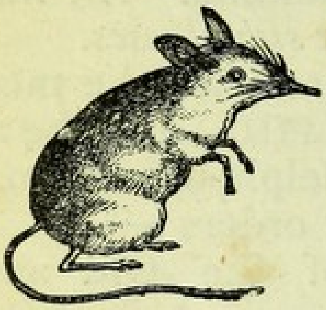

FIG. 17.—A LEAPING SHREW (*Macroscelides*).

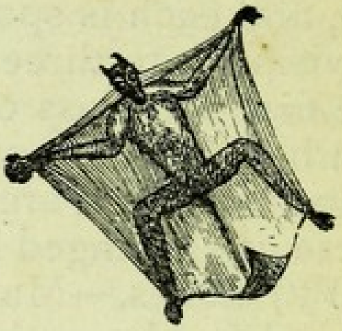

FIG. 18.—THE FLYING-LEMUR (*Galeopithecus*).

IV. RODENTIA.—Mostly rather small animals, all formed for gnawing, such as the Hare and Rabbit, the Agonti, the Beaver, the Porcupine (*Hystrix*), the Capybara, *Dolichotis*, the Squirrels, the Rats, the Australian Rat (*Hydromys*), the Jerboa (*Dipus*), the Rat-mole (*Spalax*).

V. CARNIVORA.—Beasts of prey, as the Cats, Lions and Tigers, the Hyenas, Civet-cats, Dogs, Weasels, Badger, Coatimondi, Racoon, the Ailurus, and the Bears, the Otters and Sea-otters (*Enhydra*).

VI. PINNIPEDIA.—The Seals (*Phoca*), Walrus (*Trichæchus*), and Sea-Bears (*Otaria*).

VII. CETACEA.—The Whale-bone Whales, the Sperm Whale, the Dolphins and Porpoises, including the *Pontoporia* and *Platanista* and the Narwhal.

VIII. SIRENIA.—The Dugong and Manatee, with the extinct *Rhytina* and *Halitherium*.

IX. PROBOSCIDEA.—The African and Asiatic Elephant and the extinct *Dinotherium*.

X. UNGULATA.—The Hoofed beasts, divisible into two sub-orders :—

A. PERISSODACTYLA.—Those with the functional toes of the hind foot of an odd number, as the Rhinoceros, the Tapir, the Horse and its extinct allies ; and

B. ARTIODACTYLA.—Those with the functional toes of the hind foot of an even number, as the Hippopotamus, the Hogs, the Peccaries, the Camels and Llamas, the Musk Deer, the Deer, the Giraffes, the Antelopes (including the Saiga and four-horned and prong-horned antelopes), and Oxen, Goats, and Sheep.

XI. HYRACOIDEA.—Including only the genus *Hyrax*, one species of which is "the coney" of Scripture.

XII. EDENTATA.—A very strange order, containing very diverse forms, namely: the two- and three-toed Sloths (*Cholœpus* and *Bradypus*), with the extinct

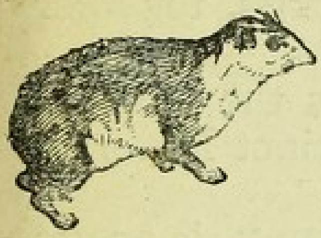

FIG. 19.—THE HYRAX.

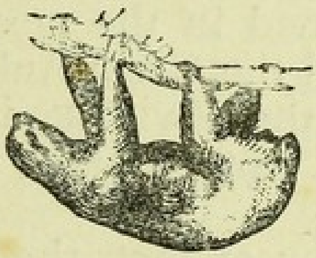

FIG. 20.—THE THREE-TOED SLOTH (*Bradypus*).

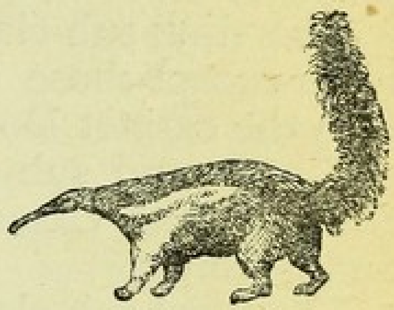

FIG. 21.—THE GREAT ANT-EATER (*Myrmecophaga*).

Mylodon and *Megatherium*, the Ant-eaters, the Pangolins (see Lesson VII. for a figure), the Cape Ant-eater (*Orycteropus*), and the Armadillos, including the extinct *Glyptodon*.

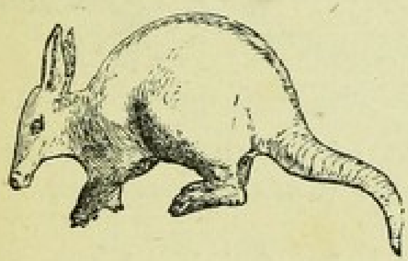

FIG. 22.—THE CAPE ANT EATER (*Orycteropus*).

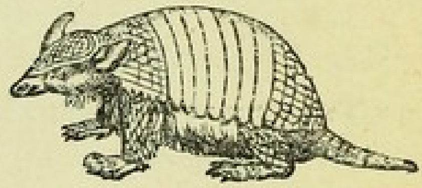

FIG. 23.—AN ARMADILLO (*Dasypus*).

The second sub-class comprises the Marsupials or pouched animals only. It is called DIDELPHIA, and the animals contained within it are termed Didelphous mammals. It consists of one order only :—

XIII. MARSUPIALIA.—A very varying group, containing the true Opossums (*Didelphys*), the Kangaroos, the Phalanges, the Wombat and Koala, the Dasyures, the Tasmanian Wolf (*Thylacinus*), the Bandicoots (*Perameles*), and *Chœropus*.

The third sub-class comprises two very aberrant genera only. It is called ORNITHODELPHIA, and the animals comprised within it are termed Ornithodelphous mammals. It consists of one order only :—

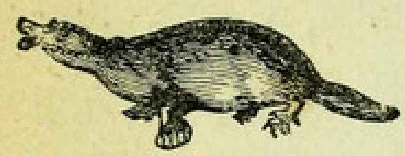

FIG. 24.—THE DUCK-BILLED PLATYPUS (*Ornithorhynchus*).

XIV. MONOTREMATA.—Of this order there are but two genera—one the Echidna, the other the Duck-billed Platypus or Ornithorhynchus.

The class *Aves* contains all the Birds (or feathered Vertebrates). It is a very uniform class, containing only three sub-classes.

The first sub-class, the CARINATÆ, comprises all living birds except those contained in the next sub-class, together with the extinct Dodo and the Great Auk.

The second sub-class, the RATITÆ, includes the Ostrich, Rhea, Emeu, Cassowary, Apteryx, and the extinct Dinornis and its allies.

The third sub-class, now extinct, the SAURURÆ, is as yet only known to have contained that bird of the Oolite, the Archæopteryx.

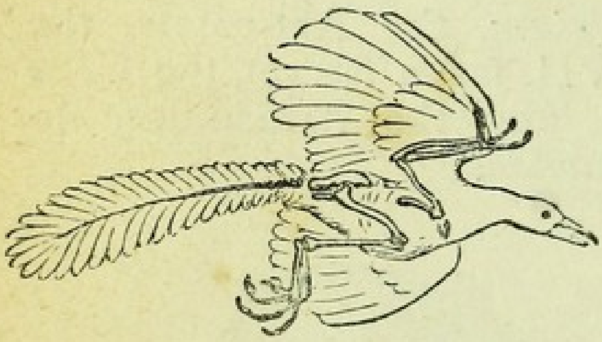

FIG. 25.—THE OOLITIC FOSSIL BIRD (*Archæopteryx*).

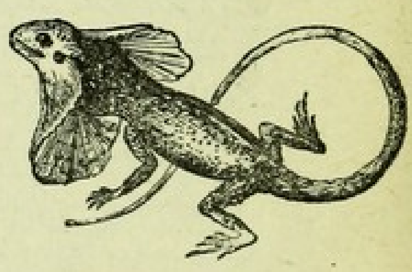

FIG. 26.—THE FRILLED LIZARD (*Chlamydosaurus*).

The class *Reptilia* embraces all the scaly, featherless, cold-blooded creatures, and consists of nine orders.

I. CROCODILIA.—An order containing only the Crocodiles, Alligators, and Gavials.

II. SAURIA.—A very numerous group, containing all the Lizards, some of which are without legs, and might be taken for serpents : the two-armed *Chirotes*, the two-legged *Bipes*, *Lialis*, the Amphisbena, the Chameleons, Geckoes, Iguanas, Monitors, Scincs (*Cyclodus*, &c.), the Agamas, the flying lizard, *Draco*, and the exceptional genus *Sphenodon*.

III. OPHIDIA.—In which are placed the harmless Snakes

(*Coluber*, &c.), the tree-snakes, the sea-snakes, and the very poisonous rattle-snakes (*Crotalus*), and Cobras, together with all other Serpents.

IV. CHELONIA.—An order containing the Land Tortoises, the Sea Turtles, and other fresh-water Terrapins, including the Matamata and the European *Emys*.

V. ICHTHYOSAURIA.—A group made up of the extinct *Ichthyosauri* of the ancient seas.

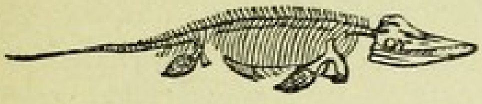

FIG. 27.—AN ICHTHYOSAURUS.

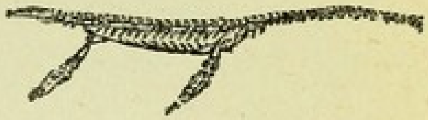

FIG. 28.—A PLESIOSAURUS.

VI. PLESIOSAURIA.—An order for the similarly extinct marine reptiles, the *Plesiosauri*.

VII. DICYNODONTIA.—Containing the genus *Dicynodon*.

VIII. PTEROSAURIA.—The extinct Reptiles of the air, which flew like our existing bats, and consisted of the genera *Pterodactylus*, *Rhamphorhynchus*, &c.

IX. DINOSAURIA.—An extinct order of large Reptiles, one of which, the Iguanodon, has left its bones on the Wealden formation of the south of England. *Iguanodon*, *Compsognathus*, and *Megalosaurus* are other interesting forms.

The class *Batrachia* is made up of four well-marked orders :—

I. ANURA.—The Frogs and Toads—a very uniform group, some genera of which, *Ceratophrys*, *Ephippifer*, *Dactylethra*, *Pipa*, &c. will be referred to hereafter.

II. URODELA.—Or the Efts and Newts, amongst which the *Menopoma*, *Menobranchus*, the two-limbed *Siren*, and the *Proteus* of the Austrian caves are worthy of special mention.

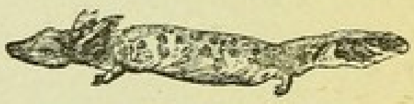

FIG. 29.—THE GREAT NORTH AMERICAN EFT, WITH PERSISTENT GILLS (*Menobranchus*).

III. OPHIOMORPHA.—This order contains limbless Batrachians with very elongated bodies, having much the appearance of small snakes.

IV. LABYRINTHODONTA.—These creatures are entirely extinct, and form the genera *Labyrinthodon*, *Archegosaurus*, *&c.*

The class *Pisces* has within it all the Fishes, *properly so* *called*, excluding Whales and Porpoises (which, as we have seen, are Beasts or Mammals) on the one hand, and Shell-fish (which are Invertebrata) on the other. This class is divisible into the following great groups :—

I. ELASMOBRANCHII.—An order of highly-organized cartilaginous fishes—the Sharks (as *Carcharias*, *Cestracion*, *Spinax*, the Hammer-headed Shark, &c.), the Rays (including *Raia*, *Myliobates*, *Aretobates*, &c.), and the Chimæra.

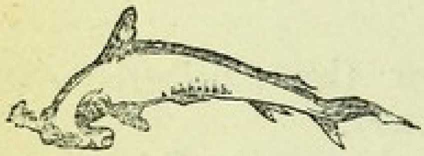

FIG. 30.—THE HAMMER-HEADED SHARK (*Zygæna*).

FIG. 31.—THE EAGLE RAY (*Myliobatis*).

II. GANOIDEI.—An important order containing many extinct forms, and a few very varied existing ones, as the *Lepidosiren*, *Ceratodus*, *Polypterus*, *Lepidosteus*, the Sturgeon, &c.

FIG. 32.—THE MUD-FISH (*Lepidosiren*).

FIG. 33.—POLYPTERUS.

III. TELEOSTEI.—The order containing the great bulk of Fishes, and including the more remarkable Siluroids (as Bagrus, &c.), the File-fishes (*Balistes*), the Trunk-fishes (*Ostracion*), the Angler (*Lophius*), and Frog-fishes (*Chironectes*), the Eels, Pike, Salmon, Carp, *Hippocampus*, *Odontoglossum*, the Soles, and other flat fishes (*Pleuronectidæ*), the Parrot-fish (*Scarus*), and very many others.

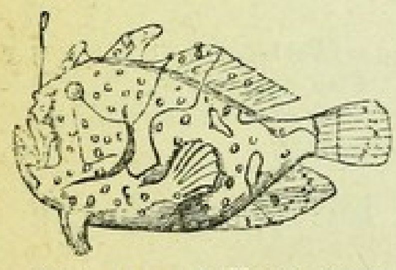

FIG. 34.—A FROG-FISH (*Chironectes*).

IV. MARISPOBRANCHII.—The Lamprey and Myxine, or the lowly-organized cartilaginous fishes.

V. PHARYNGOBRANCHII.—Containing only that headless, heartless fish without red blood—the *Amphioxus* or Lancelet.

FIG. 35.—THE LAMPREY (*Petromyzon*).

FIG. 36.—THE LANCELET (*Amphioxus*).

The foregoing list has been given to render comprehensible the references to different animals which must be so often given in the succeeding lessons.

In those lessons the several parts and organs of man's body will be examined and described, not only directly, but also in the reflected light to be derived from a knowledge of the more remarkable conditions of the same parts in other animals.

24. The organs of man's body may be divided into three classes:—

I. Organs of Investment and Support (skeletal).
II. Organs of Motion and Innervation, *i.e.* Muscular and Nervous Structures, and organs of special sense.
III. Organs of Sustentation, *i.e.* nutritive, circulating, respiratory, and excretory structures.

This division, however, is rather physiological than anatomical, so that a more convenient classification (the one to be adopted in the succeeding chapters) will be—

I. The Skeleton, both internal (*endoskeleton*) and external (*exoskeleton*).
II. The Muscular Structures.
III. The Brain and Nervous System.
IV. The Organs of Sense.
V. The Heart, Arteries, and Veins.
VI. The Alimentary Tube and its appendages.
VII. The Respiratory and Vocal Structures and the Excretory Organs.

LESSON II.

THE SKELETON IN GENERAL, THE INTERNAL SKELETON, THE BACKBONE, BREASTBONE, AND RIBS.

1. THE word "SKELETON"[1] is popularly taken to denote only the bones, or at most the bone and gristle which form the internal support of the body.

An acquaintance with other animal structures, however, shows that this signification is far too restricted; for parts which are bony in man may be cartilaginous (*i.e.* of gristle) or even merely membranous, in other animals; and conversely, parts sometimes quite external, which are merely fibrous in man, may be horn or bone, or contain bones and cartilages, in other animals.

The nature and structure of fibrous tissue,[2] of cartilage, and of bone, have been sufficiently described in the first and twelfth lessons of the "Elementary Physiology." It may, then, here be shortly stated that the word skeleton, in its widest and most scientific sense, should include not only the bones and cartilages, but also those fibrous structures (or membranes) which surround such bones and cartilages, and thence radiating invest every organ of the body, and finally clothe it externally in the form of skin.

The whole skeleton, then, may be denoted by the term Fibro-chondr-osteal[3] apparatus.

Fibrous tissue indeed penetrates the very bones themselves, and supports the marrow they contain; it separates each muscle from its neighbour, and surrounds and lines every tube and passage in the body; so that if every other tissue could be dissolved away and yet this fibrous tissue be left,

[1] Derived from σκέλλω, to dry.

[2] Each kind of substance of which the body is composed is termed a *tissue*. Thus we speak of fibrous tissue and of osseous tissue or bone, also nervous tissue, &c.

[3] Because partly fibrous, partly cartilaginous, and partly osseous.

we should have a complete outline model, as it were, of the entire human frame.

Portions of this fibrous tissue which connect adjacent bones and cartilages become very strong, and constitute the "ligaments" of the joints of the solid skeleton.

2. The skeleton as a whole is naturally divisible into two parts, to be separately treated of.

(*a*) The external, peripheral skeleton, often called the EXOSKELETON,[1] —the skin and its appendages.

(*b*) The internal, central skeleton, often termed the ENDOSKELETON.[2]

The external skeleton will be considered afterwards. First in order is the skeleton commonly so called, *i.e.* the internal skeleton.

3. The ENDOSKELETON of man is composed of numerous bones, together with cartilages and fibrous structures.

The number and nature of the solid parts vary with age. In the earlier stages of existence there are no bones at all, and the process of bone-formation (or *ossification*) having once begun, goes on till the period of adult maturity is completed, and indeed, to a less extent, throughout the whole of life.

Thus it happens that parts which are membranous in the baby or cartilaginous in the youth, become bony in the grown man; and a continuation of the same process tends to fuse together more and more, bones which at their first appearance were separate and distinct.

Indeed, besides the coalescence of distinct bones, another fusion of bony structures occurs. This is due to the fact that the ends, or projecting portions, of what are essentially and ultimately *one* bone, arise as separate ossifications, which are termed *epiphyses*.[3] Thus the ends of the long bones of the limbs are at first separate bones from the main part (or shaft) of each long bone, and do not become continuous with the shaft till near man's maturity.

The hard parts of the internal skeleton being those which as a framework support the body, form points of attachment for the muscles which move it; the muscles employing the different bones like so many levers, or fulcra, as the case may be.

4. The great majority of the bones are thus intended to move one upon another, and the contiguous surfaces of such movable bones form THE "JOINTS."

[1] From ἔξω, without. [2] From ἔνδον, within.
[3] From ἐπί, upon, and φύειν, to grow.

The nature and mechanism of the different kinds of joint have been described in the Seventh Lesson of "Elementary Physiology," as well as the different kinds of movement which the jointed bones are capable of performing. Joints may be (*a*) immovable, (*b*) mixed, or (*c*) movable.

(*a*) When bones are *immovably* joined by an interdigitation of their irregularly shaped margins (like the bones of the roof of the skull), they are said to be joined by *suture;* but they may also be immovably united by a ridge, or tongue, on one bone being received into the grooved surface of another bone.

(*b*) When the motion allowed is exceedingly slight (as between contiguous pieces of the backbone—or vertebræ), adjacent plain surfaces are connected together by the addition of fibrous substance of one kind or another.

(*c*) When the motion allowed is greater, the adjacent surfaces of the bones are coated with smooth cartilage, and motion is facilitated by a fluid called *synovial.*[1] Sometimes a third and separated cartilage (termed *inter-articular*) is placed between the cartilaginous surfaces of the jointed bones.

The most movable joints are those in which the adjacent bones are articulated on the principle either of a *pivot* (like that between the two uppermost bones of the neck), or of a *hinge* (like that of the elbow), or a *ball and socket* (like that of the shoulder).

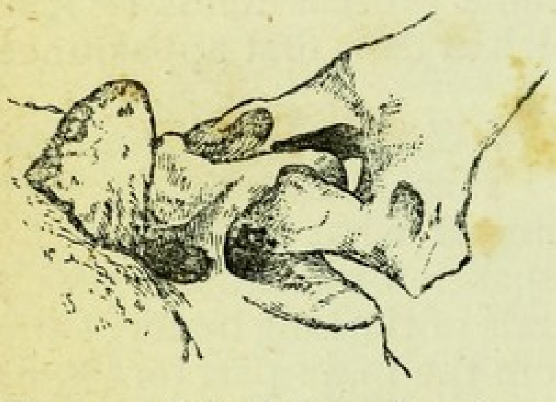

FIG. 37.—Articulation of a large spine, by shackle-joint, with a bony plate (placed below) of the skin of a Siluroid fish.

If one convex articulating surface be globular, it is termed a *head;* if it be elongated it is called a *condyle.* If either of these is borne upon a narrow portion of bone, this latter is called a *neck.* If a pulley-like surface is formed by such a juxtaposition of two condyles as to leave a depression between them, such an articular surface is named a *trochlea.*[2]

The anatomy of animals (or *zootomy*)[3] as distinguished from the exclusive study of man's own anatomy (or *anthropotomy*[4]) shows us that bones may be united in ways

[1] From σύν, with, and ᾠόν, an egg. The fluid is contained in a fibrous bag or sac.

[2] From τροχός, a pulley; τρέχω, to run.

[3] ζῶον, an animal, and τέμνειν, to cut.

[4] ἄνθρωπος, a man, and τέμνειν, to cut.

other than those observed in the human body. Thus some spiny bones of Siluroid fishes have a perforation at their base, through which passes a bony ring attached to a plate below—a *shackle-joint*. This structure, however, belongs to the external skeleton.

5. The parts of the endoskeleton may obviously be grouped into two divisions :—

(*a*) The skeleton of the head and trunk, which is called the AXIAL[1] skeleton.

(*b*) The skeleton of the limbs, which is called the APPENDICULAR skeleton, the limbs being regarded as appendages of the axial skeleton.

First with regard to the axial skeleton. The skeleton of the head (*i.e.* the skull) is supported on the very summit of what is familiarly known as the backbone, while from each side of one region of the latter the ribs reach forwards to or towards the breastbone.

The skull is of so complex a structure as to require separate consideration. The skeleton of the trunk only (that is to say, the backbone with the ribs and breastbone) will afford material enough for this lesson.

6. The backbone, or, as it is often called, the spine,[2] consists of a number of small bones placed one on the top of the other like a pile of coins.

Each of these small bones is termed a vertebra,[3] and (with certain few exceptions, to be noticed later) consists of a sort of irregular ring of bone, thickest in front, from which certain bony prominences stand out in various directions.

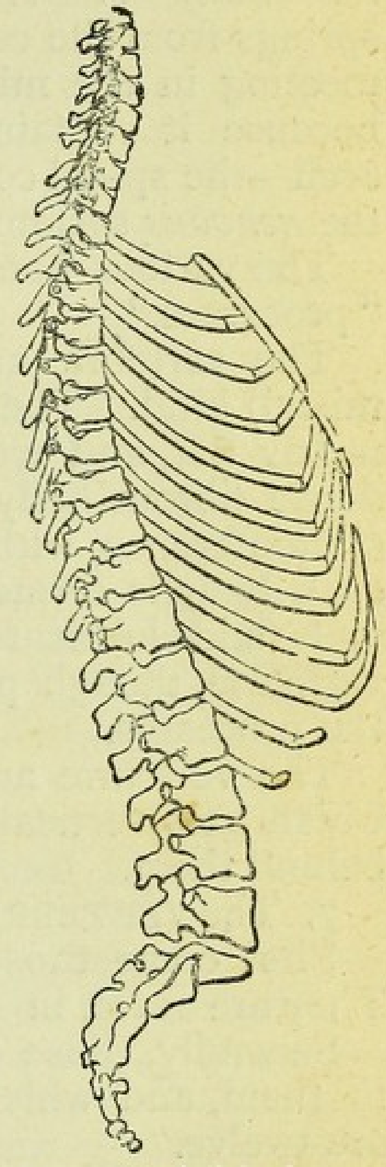

FIG. 38.—Axial skeleton of the trunk with the ribs of the right side removed to show the vertebræ more distinctly.

By the superposition of their rings, they together form a long vertical canal (called the vertebral canal), which is destined to contain and protect the spinal marrow (or spinal cord). This series of vertebræ thus constitute the smaller,

[1] From being the skeleton of what is, as it were, the axis of the body.

[2] The word "spine" is also frequently employed to denote any slender and more or less pointed prolongation of a bone.

[3] From *vertere*, to turn, though the mobility of most vertebræ is but slight.

posterior cylinder of the human trunk, spoken of in the First Lesson.

The thickened anterior parts of the vertebræ are also placed and adjusted one upon another, and by their superposition form a vertical solid column, namely, that spoken of in the first lesson as the partition separating the small dorsal cylinder from the larger ventral one.

The thickened anterior part of each vertebra is called its "body" or "*centrum.*" The ring of the vertebra (which springs from the centrum on each side of its posterior surface meeting in the middle line behind) is termed the *arch* and, because it contains part of the spinal cord, the *neural*[1] arch—the spinal cord being, with the brain, the central part of the *nervous* system.

The various bony prominences of the vertebræ are termed "processes."

The vertebræ are connected by joints of the second (or mixed) kind. Their adjacent surfaces are for the most part nearly flat, and we find interposed and connecting them a dense fibrous body or disc, toughest and hardest towards its circumference, with a pulpy substance in its middle. Each such body is termed an intervertebral substance. No synovial fluid lubricates the joints between the bodies of the vertebræ, though present between the junctions of some of the processes.

The vertebræ are also held together by strong ligaments which pass vertically down the centra, both in front of and behind them.

7. The VERTEBRÆ are divisible into five different *categories.*

First come those of the neck, which are termed *cervical.*[2] They are seven in number.

Secondly, those of the back, which have the ribs attached to them, and which bear the name *dorsal.* Of these there are twelve.

Thirdly, we find certain large vertebræ which do not bear ribs : these are situate below the dorsal vertebræ, and are called *lumbar.* There are five of them.

All the above vertebræ are termed "true vertebræ," because they do not become anchylosed together, but remain connected by ligaments and by intervertebral substances only.

Below these true vertebræ come those which are called "false," and which sooner or later anchylose together to form two bony masses.

[1] From νεῦρον, a nerve. [2] From *cervix*, the neck.

The first of these two masses, termed the sacrum, comes immediately beneath the lumbar vertebræ, and affords attachment on each side to one of the haunch, or hip, bones. Five or six *sacral* vertebræ coalesce to form the sacrum.

The second and much smaller bony mass, termed the coccyx,[1] is made up of three or four small and imperfect vertebræ, named *coccygeal.*

8. Before proceeding to consider more carefully the different vertebræ, a DORSAL VERTEBRA may first be described as a type.

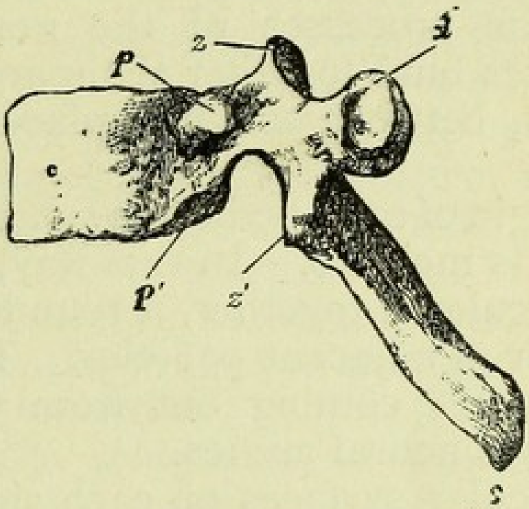

FIG. 39.—A DORSAL VERTEBRA.

c, centrum; *s*, neural spine; *d*, tubercular or transverse process; *p*, capitular process, or articular surface for the head of a rib; *p′*, small articular surface for part of the head of the succeeding rib; *z*, upper articular process, or prezygapophysis; *z′*, lower articular process, or postzygapophysis.

From each outer angle of the posterior surface of its centrum there springs a pier of the neural arch. Each of these two piers is termed a *pedicle.*

From the hinder end of each pedicle a flat plate of bone projects backwards and towards the middle line, till the two plates meet and thus complete the neural arch. Each such plate is termed a "*lamina*" or neural lamina.

At the point of junction of the laminæ a single median process runs backwards and downwards. This is the *spinous process*, or *neural spine.*[2]

From the junction of each lamina with its pedicle another process, ending bluntly, juts outwards and backwards. This is called the *transverse process*, and there are two to every dorsal vertebra.

From the upper and outer part of each lamina a small process projects upwards, with a smooth surface on it which

[1] From its fancied resemblance to a cuckoo's beak—κόκκυξ, a cuckoo.
[2] Sometimes neurapophysis, from νεῦρον, a nerve, and ἀπόφυσις, a process.

looks mainly backwards. This is called the *superior articular process*,[1] or prezygapophysis, and each dorsal vertebra has, of course, a pair of such.

From the lower and outer side of each lamina a small process projects downwards, with a smooth surface on it which looks mainly forwards. This is called the *inferior articular process*, or postzygapophysis, and there are two to every vertebra of the back.

The articular surfaces of the two inferior articular processes are applied to the articular surfaces of the two superior articular processes of the next vertebra below. Ligamentous fibres bind together the margins of the apposed articular surfaces, between which is placed a sac containing synovial fluid.

The upper margin of each pedicle is somewhat concave, while its lower margin is more so. In this way, when the vertebræ are naturally articulated together, a rounded opening appears between each pair of adjacent pedicles. These openings give exit to spinal nerves coming out from the spinal marrow enclosed within the neural arches.

Two other articular surfaces on each side should be noted: one at the outer side of the posterior and outer angle of the centrum at its junction with the pedicle, the other at the anterior aspect of the end of the transverse process. The first of these articular sources is termed "*capitular*," and the second "*tubercular*," for reasons which will appear later.

The diameter of the centrum from side to side exceeds but little its diameter from behind forwards.

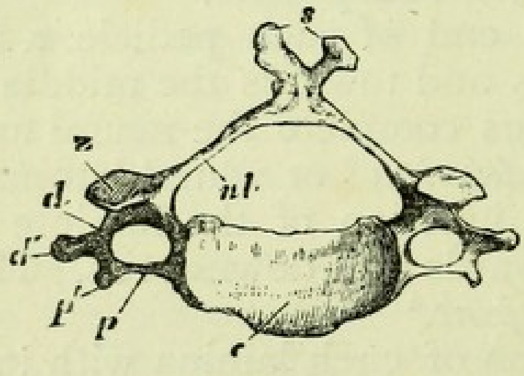

FIG. 40.—A CERVICAL VERTEBRA.

c, centrum; *s*, neural spine; *n l*, neural lamina; *d*, posterior or tubercular transverse process, or diapophysis; *p*, anterior (or capitular) transverse process, or parapophysis; *d'* and *p'*, "tubercles;" *z*, prezygapophysis.

9. Of the seven CERVICAL VERTEBRÆ, the first two are sufficiently exceptional to demand separate notice. Any

[1] From πρός, ζυγόν, a yoke, and ἀπόφυσις.

one of the other cervicals, when compared with a dorsal vertebra, presents the following characters :—

The centrum is smaller, wider in proportion to its depth, somewhat concave from side to side on its upper surface, and from before backwards on its under surface.

The neural canal and neural arch are wider, and the neural spine much smaller and shorter (except in the case of the seventh cervical vertebra), and often bifid, so that there are two irregular processes projecting side by side.

There is no long transverse process, but a short one juts out from between the zygapophyses (therefore in the situation of the transverse process of a dorsal vertebra), and another projects from the body at the root of the pedicle, just at the place where the capitular articular surface of a dorsal vertebra is placed, and so may be called the capitular process. These two short processes are connected towards their ends by a bridge of bone which extends backwards and somewhat downwards from the capitular process to the posterior process.

A space is thus enclosed on each side by the pedicle, the two processes and the bridge, and it is on this account that the cervical vertebræ are sometimes said to have perforated transverse processes.

As these processes are superimposed like the vertebræ that support them, these successive, small, bony rings form a sort of bony canal running upwards on each side of the neck-part of the backbone, and this canal serves to protect the vertebral artery which traverses it. The free end of each transverse process divides into two blunt prominences called "tubercles."

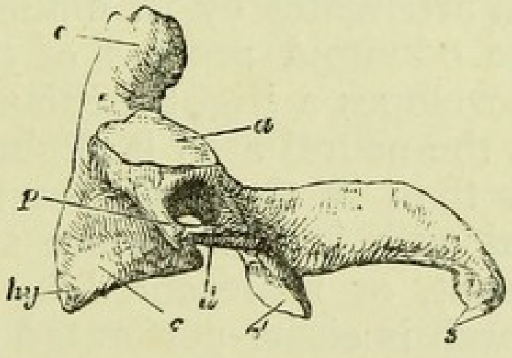

FIG. 41.—THE AXIS VERTEBRA.

c, centrum ; *s*, neural spine ; *d*, tubercular process ; *p*, capitular process ; *a*, anterior articular surface for atlas ; *z′*, postzygapophysis ; *o*, odontoid process ; *hy*, median vertical ridge beneath centrum.

10. The second cervical vertebra is peculiar, differs from every other joint of the backbone, and has a special name, the AXIS.

It differs from all the other vertebræ in having a large blunt process of bone (like a peg) continued upwards from its centrum. This is the *odontoid*[1] process, and it has on its front aspect a smooth articular surface.

The front surface of the rest of its body often bears a slightly marked median vertical prominence.

The axis also differs from all the other cervical vertebræ in having its neural spine stouter and rather more projecting, though still bifid at its apex. Moreover there are no prezygapophyses, but instead, there is on each side a large articular surface in front of the root of the capitular process.

11. The first cervical vertebra is also quite peculiar, and bears the special name "ATLAS," because it supports the head.

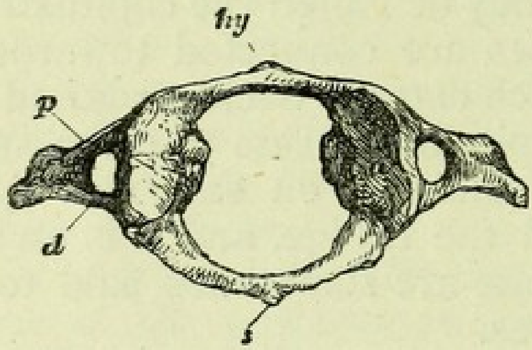

FIG. 42.—THE ATLAS VERTEBRA.

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 centrum, and articulating with the odontoid process of the axis vertebra.

It differs from every other vertebra in having no true centrum, its two lateral halves being connected together in front by a plate of bone, which articulates by its hinder surface with the front surface of the odontoid process of the axis, while its own front surface developes a slight median prominence.

While in the axis the neural arch is slightly deeper and the neural spine larger than in the other cervical vertebræ, in the atlas the neural arch is much more slender, while the neural spine is absent, or represented by a small tubercle only. The neural arch is either perforated or deeply notched above, just behind the root of the transverse process, which is longer and larger than in the other cervical vertebræ. Zygapophyses are entirely wanting, but we find a large articular surface developed both below and above the root of the transverse process of each side.

The two lower of these articular surfaces join those before

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

ıentioned as correspondingly situate on the axis vertebra. 'he upper pair of surfaces, which are larger and more up-shaped, articulate with two prominences on the base of ıe skull.

The atlas vertebra is formed to turn on the odontoid process of the axis as on a pivot. This is further explained in ıe Seventh Lesson of "Elementary Physiology."

12. Having noted the characters of vertebræ above the ypical dorsal ones, those below (*i.e.* the lower dorsal and ımbar) come next.

The lower dorsal vertebræ have their centra larger than hose of the upper, while their transverse processes become horter, and their articular processes change their direction, he upper zygapophyses looking obliquely inwards, the lower nes obliquely outwards. Finally, their neural spines project ess downwards.

In the last dorsal vertebra a small rounded prominence rises from the posterior margin of each upper articular rocess. This prominence is termed the mammillary process, r Metapophysis.[1]

Another small prominence projects backwards from etween the upper articular process and the transverse process, and is called an Anapophysis.[2]

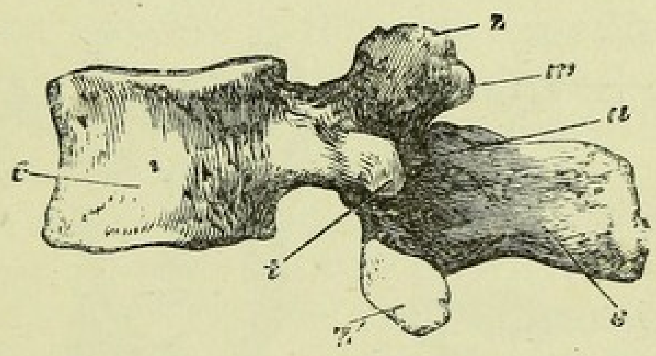

FIG. 43.—A LUMBAR VERTEBRA.

, centrum ; *s*, neural spine ; *t*, tubercular process ; *z*, prezygapophysis ; *z'*, postzygapophysis ; *m*, metapophysis ; *a*, anapophysis.

The LUMBAR VERTEBRÆ have their centra still more massive than the dorsal centra, and deeper in front than behind.

The neural spines are all more massive, and project directly ackwards instead of downwards.

The transverse processes are larger, and there are no tubercular or capitular surfaces, and no process in the place of he latter, as are found in the cervical vertebræ.

[1] From μετά, after, and *apophysis*. [2] From ἀνά, backwards.

Metapophyses and Anapophyses, visible on the first lumbar vertebra, disappear on lower ones.

13. Below the lumbar vertebræ comes a solid complex bone before mentioned—the SACRUM, of a roughly triangular form, with one angle downwards. Its front surface is strongly concave vertically, less so transversely. It is really made up of five vertebræ fused together, and plain traces of its original composition remain in the fully ossified bone of the most aged individuals.

The centra diminish in size from above downwards through the sacral series.

The neural canal, completed as usual (*i.e.* by bone) above, remains unossified and closed by membrane only at the lower end of the sacrum, through the imperfect development of the neural arches of the inferior sacral vertebræ.

Neural spines form a median, backwardly projecting ridge behind the sacrum, which ridge projects most above.

Transverse processes are largely developed, especially above. By their anchylosis they form the lateral masses of the sacrum.

On both the anterior and posterior surfaces of the sacrum four apertures, one below the other, are visible on each side. This appearance is produced by coalescence of the sacral transverse processes, thus :—

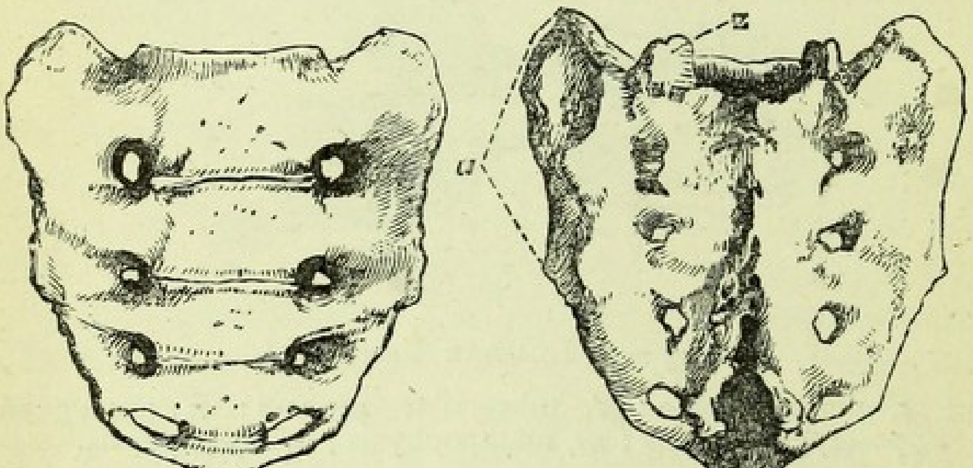

FIG. 44.—FRONT AND BACK ASPECTS OF THE SACRUM.

a, auricular surface ; *z*, prezygapophysis at upper end of posterior surface of sacrum.

Nerves, as before said, pass out on each side between the pedicles of adjacent vertebræ. Now the coalescence of the sacral transverse processes necessarily changes each such intervertebral opening into a pair of openings, of which one is dorsal and the other ventral.

At the summit of the sacrum is a pair of articular processes, which join the lower articular processes of the last lumbar vertebra.

The lower end of the sacrum is devoid of similar processes, or has them only represented by rudiments.

On each side of the upper part of the sacrum is a large irregular surface, which is coated with cartilage, and articulates with the hip or haunch bone. This is called the *auricular*[1] surface.

14. The last part of man's spine is, as has been said already, the COCCYX, which consists usually of four rudimentary vertebræ, completely or partially united so as to form a small conical bone.

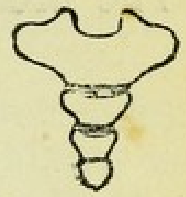

FIG. 45 —THE COCCYX. At its upper end are the two prezygapophyses.

Its uppermost part (*i.e.* the first coccygeal vertebra) articulates with the lower end of the sacrum, not only by its centrum, but also by two little articular processes; it has besides two rudimentary transverse processes and rudimentary pedicles, between which latter membrane alone extends to close the neural canal. Below this the coccyx is destitute of processes, and consists of but smaller and smaller vertebral centra fused together.

Thus the last vertebra is the very opposite of the first (or atlas), being all centrum, while the atlas has no centrum at all. The coccyx usually becomes anchylosed to the sacrum about or after the middle of life.

15. The WHOLE SERIES of vertebræ are so disposed that the backbone, when seen in profile, forms four sigmoid curves, directed alternately forwards and backwards (see Fig. 38). Thus in the neck it is slightly convex forwards, more convex backwards in the dorsal region, rather strongly convex forwards in the loins, while below this the terminal part of the column sweeps round in a more marked curvature concave in front, the coccyx continuing onwards the vertical curve of the sacrum.

These gentle curves together form a line of beauty, and give to the vertebral column a strength ten times greater than it would have were it quite vertical.

The thickness of the front part of the backbone (formed of the vertebral centra) increases slowly downwards to the

[1] From its resemblance to the outline of the external ear.

summit of the sacrum, and then decreases very much more suddenly.

The anterior surface is broadest at the neck, the loins, and sacrum, and bears no median prominences.

The posterior surface bears a median series of spines, which are longest in the last cervical vertebra and in the trunk. They are all directed either downwards or backwards—never upwards.

The true vertebræ, except the first two, are locked together by articular processes and by the bodies, which latter are united by intervertebral substances. No other articulations exist between them.

16. The breastbone, or STERNUM, extends along the front

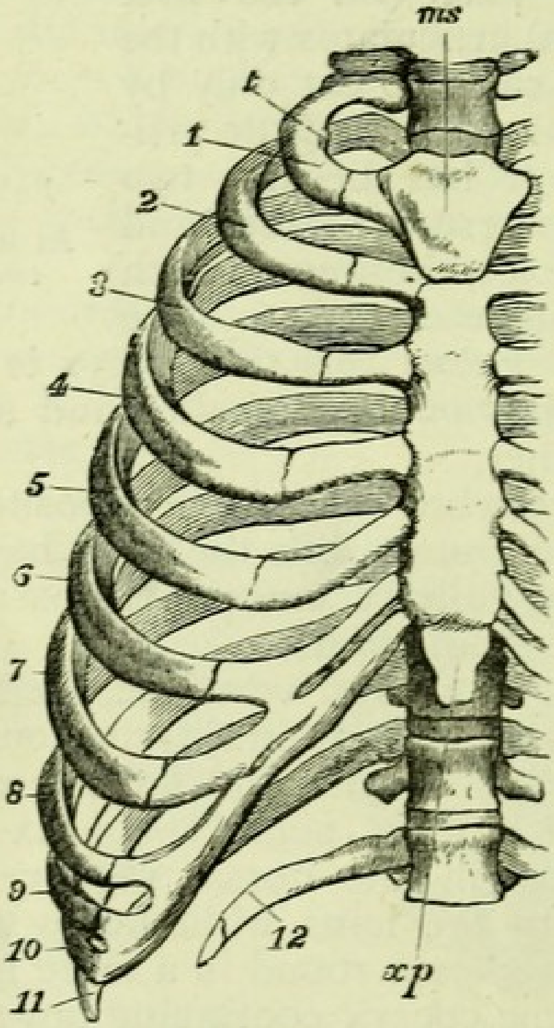

FIG. 46.—RIGHT SIDE OF THE THORAX.

1—12, the ribs; *ms*, the manubrium; *xp*, the Xiphoid process.

portion of the trunk in the middle line, but its size, complexity, and importance are very much less than the backbone's.

It receives the ends of the upper ribs, protecting the chest in front, and sheltering the heart.

The bone is flat. Of nearly equal width for the greater part of its length, it broadens out above and narrows greatly at its lower end.

The broad upper part to which the first rib is annexed is called the *manubrium* or *pre-sternum*.[1]

The narrow lower end, which projects freely and remains cartilaginous till late in life, is called the *xiphoid*[2] process.

17. The RIBS are long, slender, curved bones, which extend from the spine, and some of them join the breastbone or sternum. They are twelve in number on each side. The seven upper ribs on each side join the sternum by cartilages, and are termed "true ribs." The five lower ribs do not join the sternum, and are called "false ribs." The first rib is much stouter and shorter than the others.

Each rib, or *costa* (except the last two on each side), has a double attachment to the backbone. At its hinder end is a rounded "*head*," which articulates with the capitular surface of the dorsal vertebræ. A little distance from this there is on the outer side a rounded articular prominence called the "*tubercle*," which joins the articular surface on the anterior side of each transverse process of the dorsal vertebræ. Between the head and tubercle is a narrower interval called the "*neck*."

Each rib ends at its ventral termination in an elongated cartilage called "*costal*." Those costal cartilages which are attached to the true ribs, have somewhat pointed inner ends, and these join the sides of the sternum. Those of the false ribs either (as those of the upper three) blend with the lower border of the costal cartilage next above, or else end freely in a blunt point. The backbone and breastbone, with the ribs, form together a sort of bony cage, called the skeleton of the *thorax*,[3] which is narrow above, broad and widely open below, and wider at its greatest breadth than it is deep at its greatest depth from before backwards.

This variation in its dimension from above downwards is produced by the corresponding variation in the length of the ribs, which increases from the first to the eighth, and then gradually decreases.

18. The DEVELOPMENT of the skeleton of the trunk, or spinal endoskeleton, is briefly as follows :—

From each side of the primitive groove, mentioned in the First Lesson, a longitudinal fold extends *up* on each side

[1] A handle ; *manus*, a hand. [2] From ξίφος, a sword ; εἶδος, like.
[3] From θώραξ, a breastplate.

(called *laminæ dorsales)*, and these meeting above form a canal (the neural canal), while beneath the primitive groove runs the notochord, or *chorda dorsalis.*

Two other longitudinal folds (called *laminæ ventrales*) extend *down*—one on each side from the notochord—and ultimately meet below. Each *lamina ventralis* splits longitudinally (the split extending up towards the notochord), the

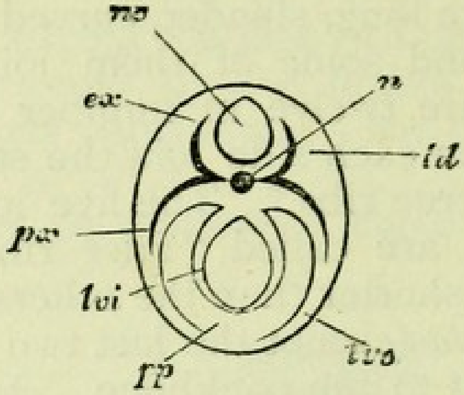

FIG. 47.—DIAGRAM OF THE DEVELOPMENT OF THE TRUNK AND ITS SKELETON AS SHOWN IN A SECTION OF THE TRUNK MADE AT RIGHT ANGLES TO ITS LONG AXIS.

ld, lamina dorsalis; *nc*, the neural canal; *n*, the notochord; *ex*, cartilage extending dorsally and forming the foundation of the neural lamina; *px*, cartilage extending ventrally in *lvo*, which represents the outer part of the split wall of the ventral lamina; *lvi*, the inner part of the split wall of the ventral lamina, forming by ventral union with its fellow on the opposite side the alimentary tube; *pp*, the pleuroperitoneal space between the outer and inner split walls of the ventral laminæ.

inner fold of each such split uniting with its fellow of the opposite side to form the alimentary canal, while the two outer folds of the split form the body wall.

Cartilage becomes deposited at intervals along each dorsal lamina, and surrounds and encroaches on the notochord, so that we come to have a series of cartilaginous segments (representing the future vertebræ), the neural laminæ of which are in the dorsal folds.

Similarly, cartilages extend down in the outer part of the split wall of the ventral laminæ. These are the cartilaginous predecessors of the ribs, which, by their fusion in the mid-ventral line, form the sternum.

Bone is deposited in the centra (nothing of the notochord being left but the pulpy substance in the middle of the inter-vertebral substances), in each neural arch, in each rib, and in successive portions of the sternum.

Besides these separate ossifications there are also the epiphyses, which long remain distinct as bony discs, one above and one below each centrum; and there are also epiphyses in the form of little bony caps to the various processes. The transverse processes of some at least of the cervical vertebræ arise as distinct ossifications, as also do the lateral bony pieces in the sacrum.

In the axis vertebra not only do the transverse processes arise as separate ossifications, but primitively both the body and the odontoid process are distinct bones, and even an epiphysis is formed between them, as well as below the centrum and at the summit of the odontoid process.

The anterior part of the ring of the atlas also arises as a separate ossification.

---

19. We will now pass on to the relations existing between OTHER ANIMALS and man with regard to the spinal skeleton. As most animals have their bodies horizontal, confusion in descriptions is apt to arise from parts being "anterior" in them which in man are "superior," and *vice versâ.* To avoid this ambiguity, it will be well to imagine an axis drawn at right angles to the general direction of the backbone. Then all parts which in man are relatively *superior*, and in beasts *anterior*, can be termed *pre-axial* in all cases ; and similarly, parts relatively inferior in man, and in beasts posterior, can be spoken of as *post-axial:* such terms referring not to the long axis of the skeleton, but to the imaginary line drawn at right angles to it.

In that man's spine is made up of distinct and ossified vertebræ, man agrees with the vast majority of the members of his sub-kingdom. Yet, in the class of Fishes, there are many examples (as in the Sturgeon, Lepidosiren, and Lamprey) of the persistence throughout the whole of life, of the notochord, or *chorda dorsalis*, of the embryo. Moreover, when the spine is fully ossified, and even in man's own class (Mammalia) it may be that the greater number of the vertebræ are anchylosed together into a solid bone, as in the extinct *Glyptodon.*

Instead of being connected as in man, the adjacent vertebræ may be connected only by synovial sacs, as in Snakes, or by intervertebral substances, perforated in the middle; and such sacs (as in Birds), or a large part of the primitive notochord (as in most Fishes), may persist between each pair of bony centra.

That degree of union which exists among the different parts of one vertebra in man, does not by any means obtain in all cases. Thus, in the extinct *Ichthyosaurus* the neural arch was permanently distinct from (*i.e.* unanchylosed with) the centrum, and in the Carp the transverse processes are separate. Even the neural arches may be made up of two separate pieces on each side, as in Elasmobranch fishes, *e.g.* *Raia* and *Spinax*.

That degree of adjustment of parts which exists in each vertebra of man is not universal. Thus, *e.g.*, we find in the Tortoises neural arches so shifted as to be respectively annexed to two centra, and thus the intervertebral foramen comes to be placed opposite the middle of each vertebral body.

A similar displacement takes place in the upper parts of the divided neural arches of the Elasmobranchs just referred to, so that the parts are united by a zigzag suture.

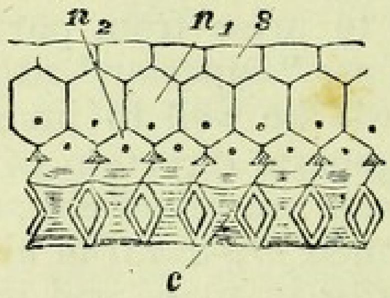

FIG. 48.—AXIAL LONGITUDINAL SECTION OF THE VERTEBRAL COLUMN OF AN ELASMOBRANCH (*Raia*).

c, one of the centra which, being bi-concave, forms lozenge-shaped sections by its junctions with the concave surfaces of adjacent vertebral centra; *s*, a neural spine; n_2, one of the dorsal parts of a neural lamina; n_1, one of the ventral parts of a neural lamina.

20. The NUMBER of vertebræ in man is far less than exists in most Vertebrates, though more than in some. No Vertebrate has much less than a third his number—even the Frogs having ten.

On the other hand, some sharks have more than eleven times as many vertebræ as man, and some serpents more even than a dozen times his number.

Man has the smallest number existing in his own class, with the exception of some Bats and Monkeys.

21. The division of the vertebræ into the five CATEGORIES of man's vertebral column is common to most forms above Fishes, but we may find the lumbar vertebræ indistinguishable and the sacral absent; and in Fishes we can hardly define even a single cervical, the vertebræ being reduced to but two categories, namely, those of the trunk and those of the tail.

The division of the vertebræ into *true* and *false* is seen to be a very arbitrary one when we extend our view, as all are "true" in Serpents, and those which are "false" in man are true even in some members of his own class, *e.g.* the Cetaceans. On the other hand, many vertebræ which are reckoned to be "true" in him are "false" in other animals. Thus, in Birds the process of anchylosis invades the lumbar and dorsal vertebræ. In Tortoises all the trunk vertebræ are fused, and therefore "false," while in the Glyptodon none of the vertebræ except the coccygeal can be said to be "true" ones.

Again, vertebræ may be more thoroughly "false" than even in man, as in the sacrum of the Rhea (or American Ostrich), where between the hip-bones they abort, and are represented only by a long narrow strip of bone. Distinct vertebræ are developed both pre-axially and post-axially to this strip. "Degradation" is a constant character of the last vertebræ in all classes of Vertebrates.

22. As to VERTEBRÆ IN GENERAL, the neural arch is *the* constant character of a vertebra—persisting even where (*e.g.* in *Lepidosiren*) the bodies are not formed.

Two neural arches may correspond to one centrum, as in some Elasmobranchs; and merely cartilaginous neural arches may exist, as in the Sturgeon. The arch may present processes which are not developed in man. The two laminæ may (as on the Axolotl) fail to meet together on the dorsal aspect.

The centrum, or body, may have its opposite surfaces strongly convex or concave, contiguous vertebræ uniting by a ball and socket joint, instead of being flat or nearly so, as in man.

The ball may be post-axial in each vertebral body, a structure termed *procœlous*,[1] and found *e.g.* in existing crocodiles; or the ball may be pre-axial, which condition is called *opisthocœlous*,[2] and is more rare, but is found *e.g.* in the land Salamander, and even in man's own class, as in the cervical vertebræ of the Ruminants.

The vertebræ may have both surfaces hollow, a structure called amphicœlous;[3] or bi-concave, a condition found in most Fishes, and even some Reptiles, as the Geckoes. The osseous bodies may be reduced to mere rings encircling the

[1] From πρό, before, and κοῖλος, hollow.
[2] From ὄπισθε, behind, and κοιλος.
[3] From ἀμφί, both, and κοῖλος.

notochord, as in some Elasmobranchs, or to mere cartilaginous rudiments in its sheath.

Sometimes (as in the first coccygeal vertebra of the crocodile) a vertebra may be bi-convex, or have a ball at each end; and very rarely two prominences or two hollows may exist side by side on one surface of a centrum, as in some cervical vertebræ of Chelonians.

The articulating processes (zygapophyses) are very constant structures, and are substantially as in man, except that

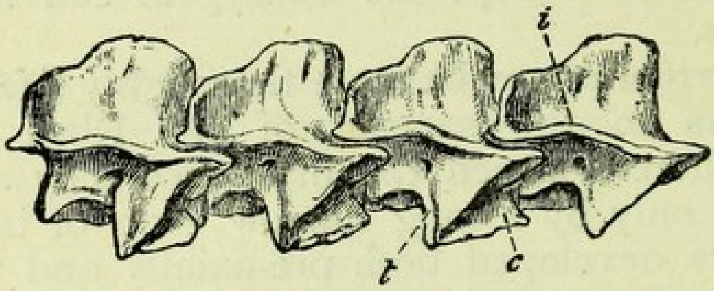

FIG. 49.—LATERAL VIEW OF FOUR TRUNK-VERTEBRÆ OF SIREN.
c, capitular process; *t*, tubercular process; *i*, interzygapophysial ridge.

in fishes they cannot be said to articulate truly. A strong interzygapophysial ridge may connect together the pre- and post-zygapophyses of each side of a vertebra, as in Siren.

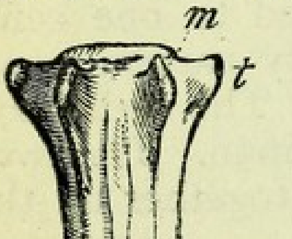

FIG. 50. - UPPER SURFACE OF TWELFTH CAUDAL VERTEBRA OF LEOPARD, ⅜.
m, metapophyses; *p*, processes serially continuous with those which support the posterior zygapophyses in the anterior vertebra; *t*, transverse processes; *t'*, anterior transverse process.
(*From Prof. Flower's "Osteology."*)

The transverse processes are structures too complex to be more than referred to under this general heading. The conditions exhibited by them in man are such as obtain generally, but by no means universally, in Vertebrates above fishes. Two transverse processes may be developed from each side of the same vertebra and in the same plane. This may be seen in the posterior coccygeal vertebræ of Apes and other Mammals, and at least occasionally in some vertebræ of *Polypterus*.

The spinous processes of man are less developed than in the Vertebrata generally. They are, however, considerably more so than in many Vertebrates, *e.g.* than in Bats and Birds. Their occasionally bifid condition in man may be repeated in much lower Vertebrates (*e.g.* Axolotl), and sometimes (as in *Polypterus*) there may be two neural spines to one vertebra, one in

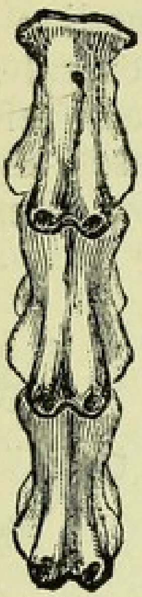

FIG. 51.—Dorsal view of Sixth, Seventh, and Eighth Post Sacral Vertebræ of the Axolotl, showing the laterally bifurcating neural spines, each concave at its extremity.

(*From the College of Surgeons' Museum.*)

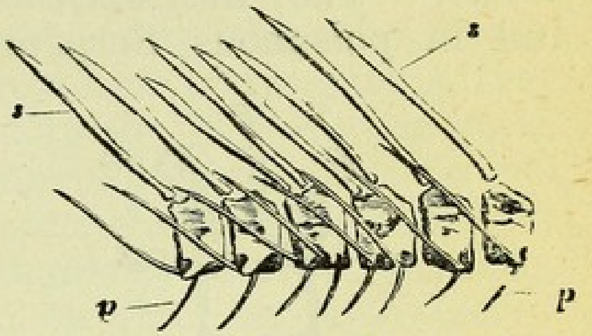

FIG. 52.—SIX TRUNK-VERTEBRÆ OF POLYPTERUS.

The third and fourth vertebræ have each two transverse processes and four ribs on the side shown; the third vertebra has also two neural spines. *s*, neural spine; *p*, lower ribs. The series of upper ribs is not distinguished by any letter.

(*From the College of Surgeons' Museum.*)

the front (*i.e.* pre-axial) of the other. Indeed, in the Conger we have two such projections from each side of the neural arch.

In certain flat fishes they may be detached from the arches and intercalated between them. They may expand and simulate dermal scutes, as in the Tortoises. They may project through the skin of the back, as in the Potto, or be produced into long, free filamentary processes, as in the Lizards called Basilisks.

The intervertebral foramina of man are normal, but in

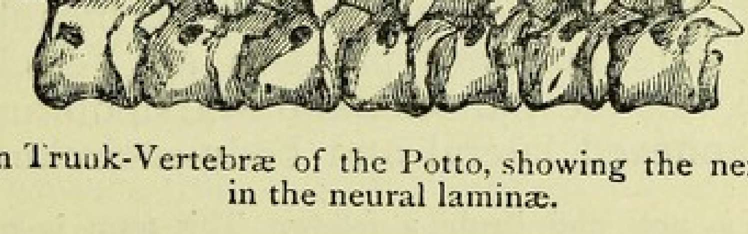

FIG. 53.—Seven Trunk-Vertebræ of the Potto, showing the nervous perforations in the neural laminæ.

some animals, even so nearly allied to man as the Potto, also in the Horse, Ox, Monotremes, and others, the nerves pass out through perforations in the neural arches themselves, and not between the notches of contiguous arches.

There may be additional parts and processes which are quite wanting in man, except as represented by the slight median ridge in front of the axis vertebra.

Such are the processes (sometimes median and azygos,[1] sometimes paired) which appear on the ventral aspect of the centrum in many animals, and which are termed *hypapophyses*.[2] They may exist as single processes, as in the Hare and in poisonous Serpents, which have them developed

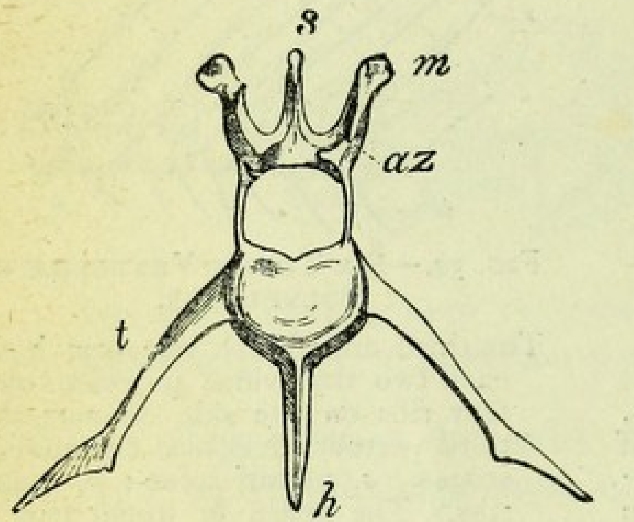

FIG. 54—ANTERIOR SURFACE OF THE LUMBAR VERTEBRA OF HARE (*Lepus timidus*).

s, spinous process ; *m*, metapophysis ; *az*, anterior zygapophysis ; *t*, transverse process ; *h*, hypapophysis.

(*From Prof. Flower's "Osteology."*)

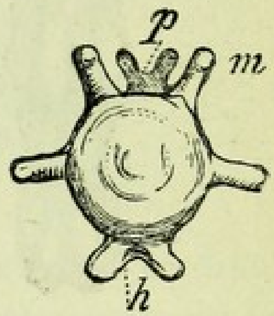

FIG. 55.—ANTERIOR SURFACE OF TWELFTH CAUDAL VERTEBRA OF LEOPARD.

m, metapophysis ; *p*, processes serially continuous with those which support the posterior zygapophyses in the anterior vertebra ; *h*, hypapophyses. The process on the side of the body between *m* and *h* is the anterior transverse process.

(*From Prof. Flower's "Osteology."*)

throughout the greater part of the vertebral column. In the harmless snake *Rachiodon* some of these processes extend into the œsophagus (swallow), and becoming coated with a toothlike substance, act as teeth. Hypapophyses may be developed as paired processes, as in the coccygeal vertebræ of many beasts, or they may be in the form of Y-shaped arches, as we commonly find them beneath some or other of the coccygeal vertebræ when these latter are large and numerous.

23. DORSAL VERTEBRÆ, if by that be meant "vertebræ bearing ribs," are constant parts in all Vertebrates, save those in which, like the Lancelet and Marsipobranchs, neither vertebræ nor annexed lateral and body-encircling structures

[1] Azygos, from ἀ, not, and ζυγός, a fellow. This term is applied to parts which are single, as opposed to those which exist in pairs.

[2] From ὑπό, under, and *apophysis*.

become distinctly solidified. Inasmuch, however, as man's dorsal vertebræ form a series the first of which bears ribs which join a sternum, man agrees with all Vertebrates (except Serpents) above the Ichthyopsida; but he differs from the whole of the last-named vast group, as in that group there is either no sternum or else no ribs which join it.

In their number the dorsal vertebræ of man are a little below the average of his class, in which the number may be augmented to twenty, as in the Elephant, or doubled (*i.e.* twenty-four) as in the Two-toed Sloth, or on the other hand reduced to ten, as in Azara's Armadillo. Comparing the condition existing in man with that in the Non-Mammalian Vertebrates above Fishes, we find his number to be smaller than that in most Reptiles, but somewhat greater than in Birds, where, on account of the prodigiously enlarged sacrum, but three (e.g. *Ciconia alba*), seven or nine, or, very rarely, eleven vertebræ are reckoned as dorsal.

In the main proportions of the centrum (the greater height in proportion to breadth, smaller medullary canal, elongated spinous processes, the articular process, short transverse processes, and considerable lateral notches), these vertebræ in man agree with those of other Mammals.

Often, however, the spinous processes may be very much more prolonged, as in the Ungulata (*e.g.* the Ox and the Horse), or they may be swollen at their summits, and more or less anchylosed together, as sometimes in the true Opossums. On the other hand, they are sometimes almost or quite absent, as in Bats.

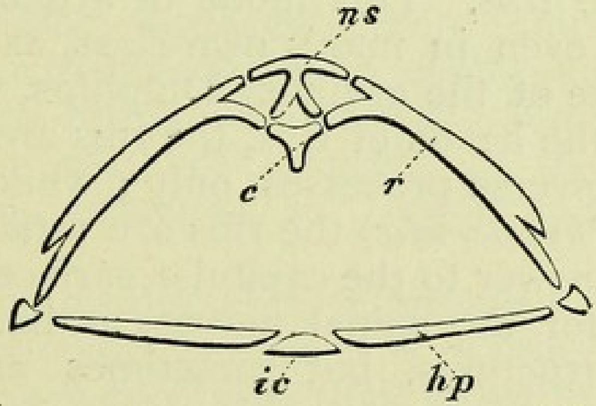

FIG. 56.—DIAGRAM OF A SECTION OF SHELL OF A TORTOISE MADE TRANSVERSELY TO THE LONG AXIS OF THE SKELETON.

ns, neural spine; *r*, rib; *ic* and *hp*, ventral plates not belonging to the true axial skeleton.

The most remarkable modification of dorsal vertebræ is that in Tortoises and Turtles, where the neural spines expand at their summits into wide plates which articulate by suture with each other and with similarly expanded ribs, to form the "shell" or carapace. These plates are so externally situate as to be invested only by a horny form of skin.

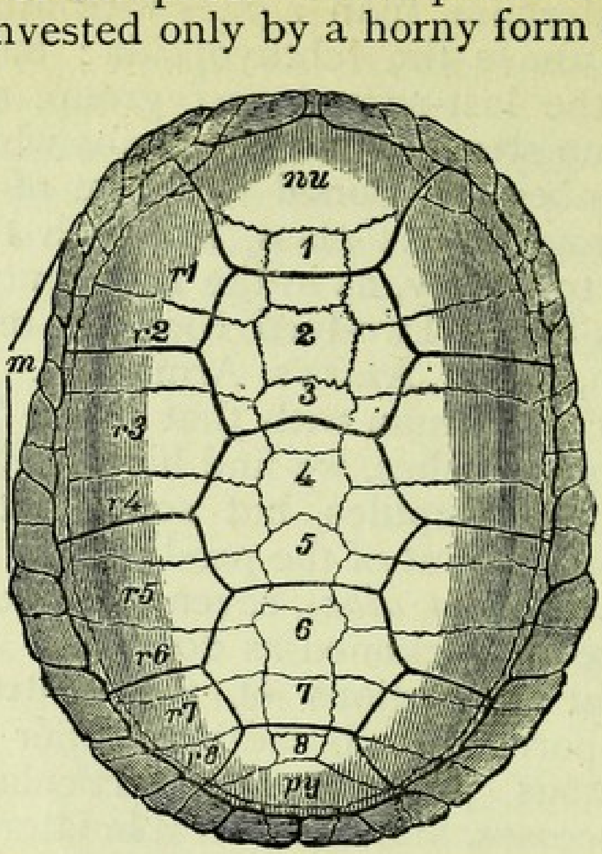

FIG. 57.—DORSAL SURFACE OF A SHELL OF A FRESH-WATER TORTOISE (*Emys*).

1—8, expanded neural spines; r^1—r^2, expanded ribs. (The dark lines indicate the plates of the horny investment of the skeleton.)

The transverse processes generally articulate with the tubercles of the ribs, while the sides of the bodies bear the heads of the ribs. This mode of articulation, however, is not constant even in man's own class, as in the posterior thoracic vertebræ of the ordinary Dolphins, where there are no surfaces for the heads of ribs, the ribs are attached to the ends of the transverse processes only; while in the Sperm Whale group (*Physeteridæ*) the ribs are attached exclusively to parts which answer to the capitular surfaces of man.

The notches for the spinal nerves, as has been said, are not constant structures, but sometimes are replaced by direct perforations of the neural laminæ.

The flatness of the surfaces of the vertebral bodies in man is a condition constant in his class, but in Birds these surfaces are concave in one direction and convex in another. A ball and socket or a bi-concave articulation is to be found in yet lower forms.

That the only articular vertebral processes are the zygapophyses, is a character man shares with most of his class. It is possible, however, for the neural spine to send back a pair of processes (hyperapophyses[1]), as in Galago, &c., embracing the neural spine next below, or, as in Dolphins, that a pair of metapophyses may project pre-axically from one spine and embrace that of the next vertebra. These, however, do not support articular processes, and are rather checks than joints.

But a much more complex mode of articulation is possible. Thus, in Serpents and Iguanas we may have a median prominence with two articular surfaces, developed from the pre-axial surface of the neural arch, and fitting into a corresponding concavity on the post-axial surface of the vertebra in front.

This pre-axial wedge-shaped process is called the *zygosphene*,[2] and the corresponding post-axial excavation is termed the zygantrum.[3]

The maximum of dorsal joint complication, however, is found in the last dorsal vertebra of certain Edentates, *e.g.* the Great Ant-eater. Here each postzygapophysis develops two additional articular surfaces, one on each side of a notch, which receives a process from the pre-axial side of the neural arch, which process is furnished with two corresponding surfaces — there thus being three articular surfaces on each side of such vertebra, fitting into corresponding surfaces of the vertebra adjacent in the mode known in carpentry as "tenon and mortice."

In so far as man's dorsal vertebræ are all free (*i.e.* true vertebræ), he agrees with other Vertebrates, except such abnormal forms as Chelonians and the Glyptodon, and except also Birds, in which anchylosis unites a greater or less number of the vertebræ next the lumbar region.

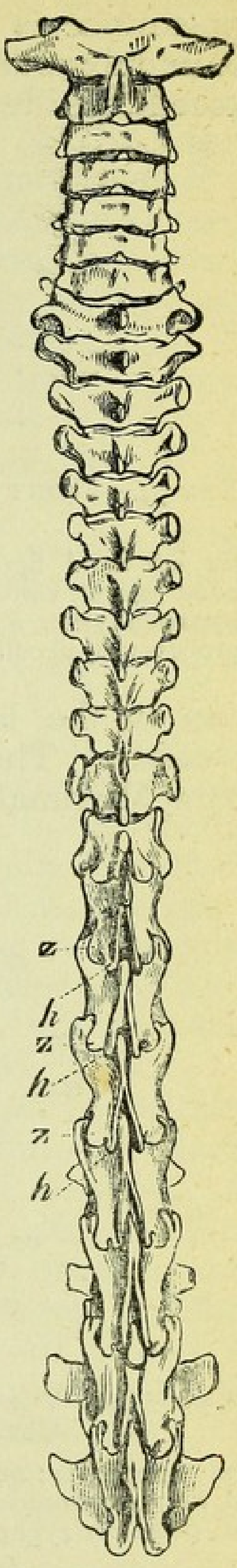

FIG. 58.—SPINAL COLUMN OF GALAGO.

z, postzygapophyses; *h*, hyperapophyses.

[1] From ὑπέρ, beyond, over, and *apophysis*.
[2] From ζυγόν, a yoke, and σφήν, a wedge.
[3] From ζυγόν, and ἄντρον, a cavity.

Those small and insignificant processes which make their appearance as mere rudiments on the last dorsal of man are commonly much larger in other Mammals, and may be exceedingly developed; as, however, they attain their maxi-

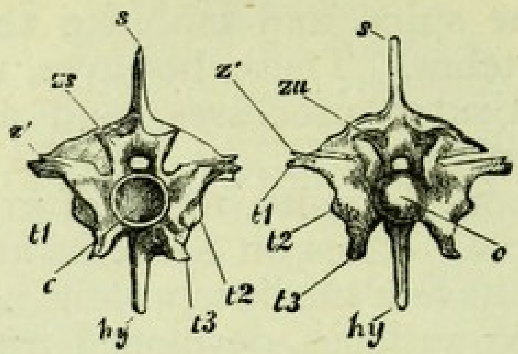

FIG. 59.—FRONT AND BACK VIEW OF A VERTEBRA OF A RATTLE-SNAKE (*Crotalus*).

c (in left-hand figure), concavity of pre-axial surface of centrum; *c* (in right-hand figure), convexity of post-axial surface of centrum; *s*, neural spine; *hy*, hypapophysis; *z'*, post-zygapophysis; t^1, tubercular process; t^2, capitular process; t^3, peculiar extra transverse process; *za*, zygantrum; *zs*, zygosphene.

mum in the lumbar region, they will be better described hereafter. They are not certainly present in Vertebrates below Mammals. But in some Chameleons (e.g. *C. Parsonii*)

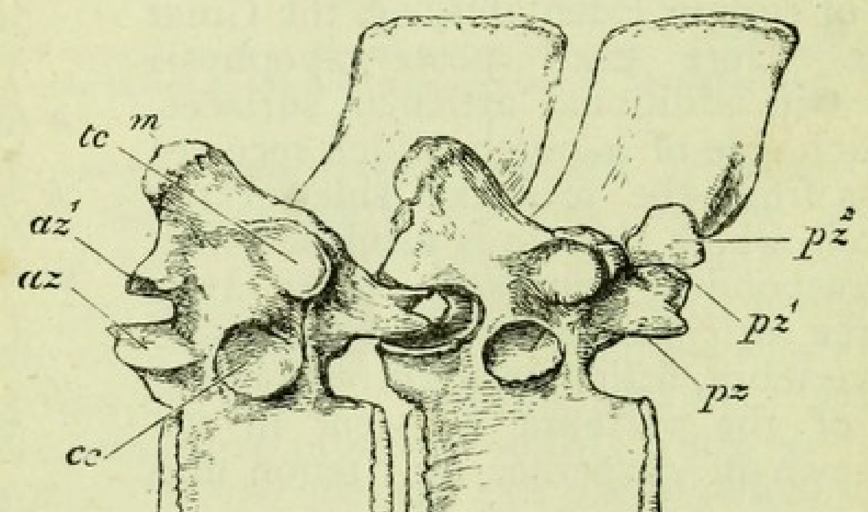

FIG. 60.—SIDE VIEW OF TWELFTH AND THIRTEENTH THORACIC VERTEBRÆ OF GREAT ANT-EATER (*Myrmecophaga jubata*), ⅜.

m, metapophysis; *tc*, facet for articulation of tubercle of rib; *cc*, ditto for capitulum of rib; *az*, anterior zygapophysis; az^1, additional anterior articular facet; *pz*, posterior zygapophysis; pz^1 and pz^2, additional posterior articular facets. (*From Professor Flower's "Osteology."*)

a prominence is developed from each prozygapophysis, which may be a metapophysis, and this attains a very great size in some Colubrine snakes. In Birds such a process exists, though less developed, in the posterior cervicals of the Great Auk.

The articular surfaces which support the ribs in man are normal in his class. Sometimes, however, each vertebra carries but one surface—that for the head of the rib (as in the Dolphin). The two articular surfaces may coexist at different levels on one single process, as in the dorsal vertebræ of the Crocodile; or they may be in close apposition, and, as it were, fused together, as in Serpents; or they may be raised on two quite distinct processes—one dorsal, the other ventral—as in the Ichthyosaurus and in *Menobranchus*.

We find in some serpents peculiar processes (Fig. 59, t^3) extending ventrally and pre-axially from the base of the inner side of the transverse processes.

The even surface of the anterior (ventral) aspect of the dorsal vertebræ of man is very different from what we find in some animals, as *e.g.* the Penguin, Cormorant, and many serpents, where there are long hypapophyses equalling or exceeding the neural spines in length.

24. The CERVICAL VERTEBRÆ of man, in that they are seven in number, conform to a law which is singularly constant in his class, whatever the length of the neck, whether it be extremely long, like that of the Giraffe, or like that of the Porpoise, reduced to a minimum. Nevertheless, this law is not absolutely universal, as there are one or two singular exceptions amongst Mammals. Thus the Three-toed Sloth has nine cervical vertebræ, while one of the Two-toed kind (*Cholæpus Hoffmannii*) and the Manatee have but six.

In Sauropsidans the number is greater, and sometimes there are as many as twenty-five, as in the Swan. In Batrachians but a single vertebra can be called cervical, and none merit the name in the class of Fishes. Nevertheless, the first three or four vertebræ next the head may, in some fishes, present a marked difference from those vertebræ which succeed, being much elongated and all united by suture, as in *Fistularia* and *Bagrus*, and they may, as in the latter fish, develop a continuous hypapophysial canal. The second and third vertebræ may form a hollow bladder-like case of bone, as in *Cobitis*, or send outwards or downwards special processes, as in the Carp.

In that the cervical vertebræ of man are smaller than those in the other regions, he agrees with many animals and differs from many. They may be (as in Bats and in their extinct precursors, the Pterodactyles) absolutely larger in all respects than any other vertebræ. They may be (as in the Giraffe, and indeed in Ungulata generally) larger than more post-axial ones. On the other hand, they may be excessively reduced—mere delicate laminæ of bone, as in Porpoises. The free condition of man's cervical vertebræ is normal and

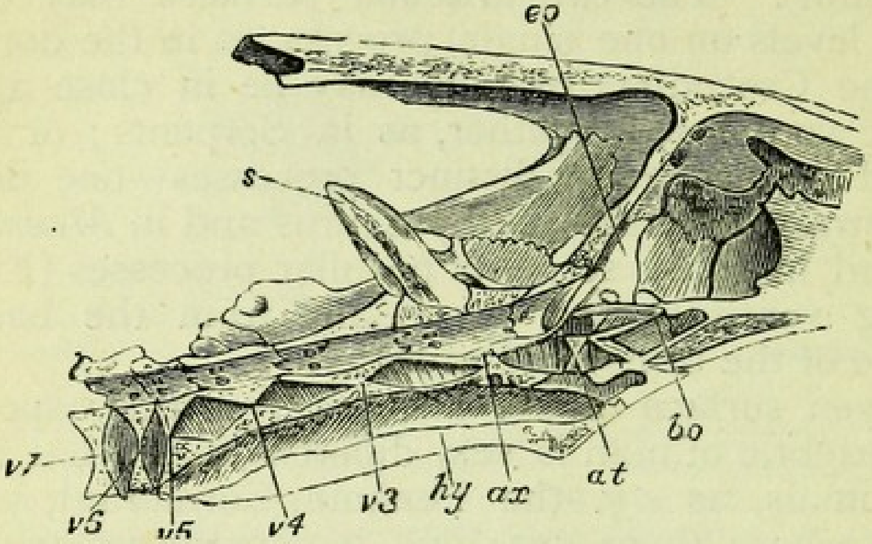

FIG. 61.—SECTION OF MOST PRE-AXIAL VERTEBRÆ, AND PART OF SKULL OF SILUROID FISH, *Bagrus*.

(*From Professor Owen's "Archetype of the Skeleton."*)

at, *ax*, *v* 3, *v* 4, *v* 5, *v* 6, and *v* 7, centra of the seven most pre-axial vertebræ; *s*, neural spine of second vertebra; *eo*, ex-occipital; *bo*, basi-occipital; *hy*, hypapophysial plate extending along on ventral side of vertebral centra. The lateral parts of the first two vertebræ (between *eo* and *s*) are united by suture with each other and the skull.

almost constant in his class. Not quite so, however, for in the true Whales they usually become anchylosed together, so as to form a sort of cervical sacrum. They may, on the contrary, be distinguished as the *only* free vertebræ except the coccygeal ones, as is the case in Tortoises; and as in Birds, where the long and very mobile neck has to supply the place of an arm in supporting a beak which rivals in delicacy of action any hand and fingers known to us, as is manifest from the wonderful construction of their many kinds of nest.

That part of each cervical vertebra which is called the *body* varies as to shape in the way just described in speaking of the cervical vertebræ considered as whole and entire bones.

The pre-axial concavity and post-axial convexity which the bodies exhibit, represent the much more marked concavity and prominence which we find in some Mammals, *e.g.* the Sheep and Horse.

In the lowest Mammals (Echidna and Ornithorhynchus) the cervical transverse processes remain as distinct more or less

Y-shaped bones; and we find the same in the Crocodile, where the free end of each Y-shaped bone is singularly pro-

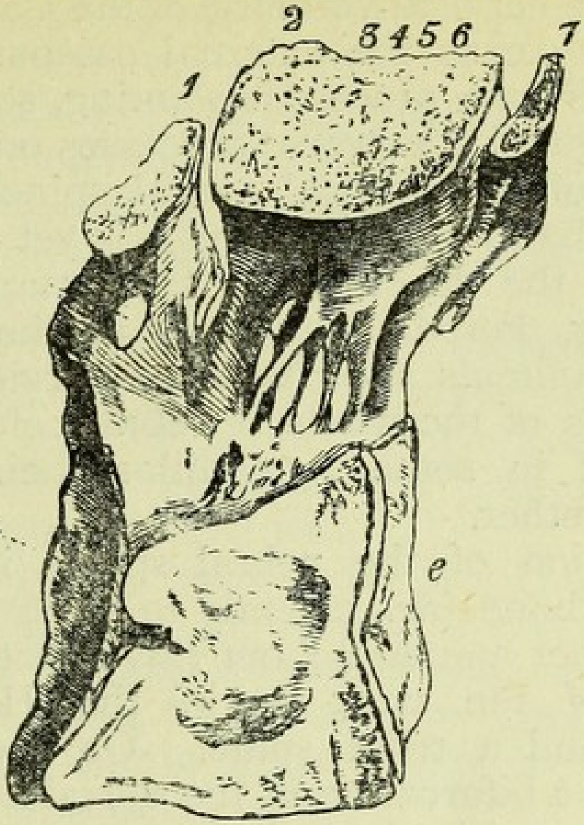

FIG. 62.—SECTION THROUGH MIDDLE LINE OF UNITED CERVICAL VERTEBRÆ OF GREENLAND RIGHT WHALE (*Balæna mystutus*).

a, articular surface for occipital condyle; *e*, epiphysis on posterior end of body of seventh cervical vertebra; *sn*, foramen in arch of atlas for first spinal nerve; 1, arch of atlas; 2, 3, 4, 5, 6, conjoined arches of the axis and four following vertebræ; 7, arch of seventh vertebra.

(*From Prof. Flower's "Osteology."*)

longed in the line of the backbone—*i.e.* pre- and post-axially. In many lizards and birds the posterior cervicals bear long

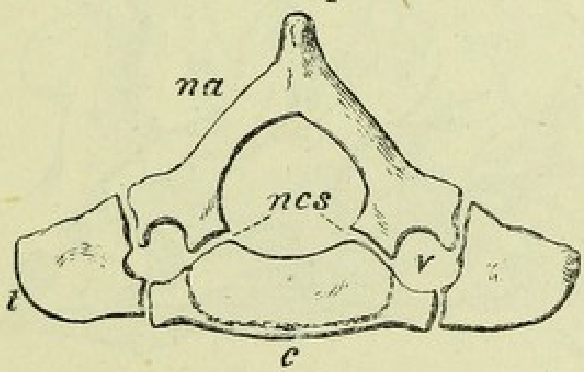

FIG. 63.—Third Cervical Vertebra of a nearly full-grown Echidna (*E. hystrix*), the different pieces of which it is composed being slightly separated from one another.—*na*, neural arch; *c*, centrum; *t*, transverse process; *v*, arterial canal; *ncs*, neuro-central suture.

(*From Prof. Flower's "Osteology."*)

ribs, and are only counted as cervical because their ribs do not join a sternum, which yet is attained by the ribs of other vertebræ.

The canal formed by the series of perforated transverse processes may be replaced by one excavated inside the neural arches, as in the cervical vertebræ of the Camels and Llamas.

In some Cetaceans the external osseous boundary of the perforated transverse process is wanting, so that there come to be two elongated transverse processes on each side.

The length of the cervical neural spines in man, though much greater than in many animals, is yet quite insignificant compared with the development they attain in certain Apes (Gorilla, Orang, Perodicticus) and in the true Opossums. Indeed, these animals show that the cervical spines may be the longest ones of the whole vertebral column. In the true Opossums and in some Armadillos their apices become anchylosed together.

The bifurcation of the neural spines is carried further down the backbone (*i.e.* extends to more vertebræ) in man than in any other mammal; but this is not the maximum of complication of the part, as in the Howling Monkeys (*Mycetes*) we find a trifid spine. On the other hand, we often meet with a bifurcation in the dorsal and lumbar regions which is not present in the human skeleton.

That faintly-marked prominence which exists in man in front of the prezygapophysis is really a rudiment of a metapophysis, as is plainly shown by the skeleton of the Spider Monkey (*Ateles*).

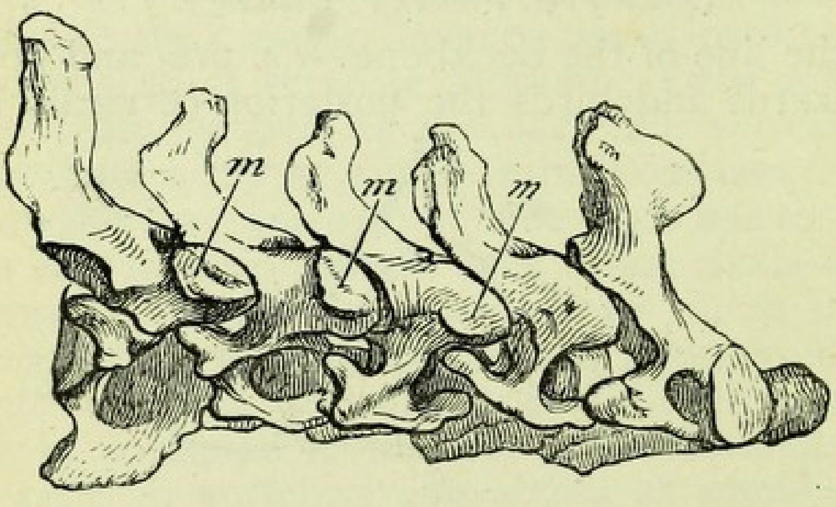

FIG. 64.—AXIS AND FOUR FOLLOWING CERVICAL VERTEBRÆ OF A SPIDER MONKEY (*Ateles*).

m, metapophysis.

The smoothness of the anterior surface of the cervical vertebral bodies in man is a great contrast to their condition in some animals (as *e.g.* in Birds); for prominences (the hypapophyses) on the post-cephalic vertebræ may (as in *Crotalus*) equal, if they do not exceed, the neural spines in length. Hyperapophyses may exist upon the postzygapophyses of the anterior cervical vertebræ, as in the Dog.

25. In the preponderating size of the LUMBAR VERTEBRÆ man but exaggerates a character generally present in his class, but this preponderance is not universal, as is shown by Bats. Lumbar vertebræ are generally to be distinguished in Mammals, and in Crocodiles and certain Lizards, but not in any Ichthyopsidan.

In Birds, lumbar vertebræ are present indeed, but disguised and hidden by exaggeration of the sacral anchylosis.

The number in man is below the average of his class, though some Apes have but four, the Two-toed Sloth but three, and the Monotremes but two.

The largest number in quadrupeds is eight, or sometimes nine, found in the Slow Lemur—which is very remarkable, as in that beast there are also sixteen dorsal vertebræ. There may indeed be as many as twenty-four lumbar, as in the Dolphins, though the limits of the region are somewhat indeterminate in those animals.

The spinous and transverse processes of the lumbar vertebræ are shorter relatively in man than in most Mammals, which also have them generally directed towards the head. The lumbar transverse processes may be excessively prolonged, as in Cetaceans, and the last ones may articulate or anchylose with the sacrum, as in the Horse.

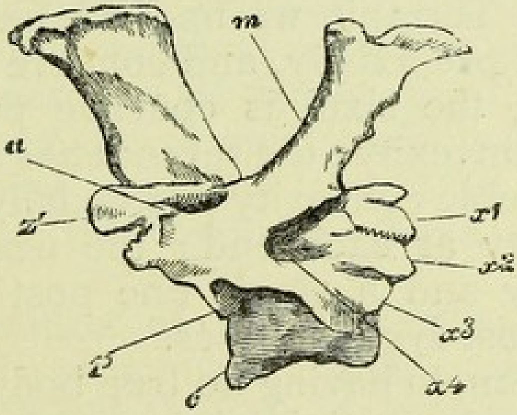

FIG. 65.—LUMBAR VERTEBRÆ OF THE GREAT ARMADILLO (*Priodontes*).

c, centrum; *s*, spine; *p*, capitular process; *z'*, postzygapophysis; *m*, metapophysis; *a*, anapophysis; x^1, x^2, x^3, x^4, four contiguous but distinct articular surfaces.

(*From the College of Surgeons' Museum.*)

The metapophyses and anapophyses attain their greatest length in the lumbar region: thus in the Armadillos the former processes equal the spinous processes in length, and serve to support the bony shell of those animals. In *Priodontes* the metapophyses are enormous, and there are four articular surfaces on each side of each end of a lumbar vertebra.

In addition to the complexity of articulation described as existing on the last dorsal vertebra of the Great Ant-eater, we find in this animal's lumbar region an additional articular surface on each side of each transverse process.

A long hypapophysis may be developed, as in the Hare. Instead of being free, as in man, the lumbar vertebræ may be anchylosed together and with other parts, as in Birds, the Chelonians, and Glyptodon.

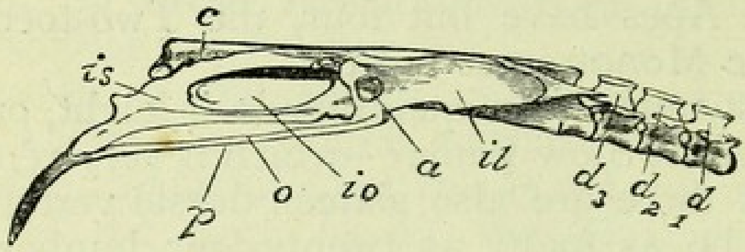

FIG. 66.—PELVIS OF A BIRD ANCHYLOSED TO THE LUMBAR VERTEBRÆ.
d_3, last free dorsal vertebra; *c*, coccygeal vertebræ; *il*, ilium. (For the other letters see Lesson V.)

26. Inasmuch as the first two vertebræ and no more are specially modified, man agrees with all birds and beasts, and differs from all below. The specialization may, however, be even greater than in him, as is the case with Chelonians, where each cervical has its own peculiarities. Thus in the common european Terrapin we find the fourth cervical with its centrum convex pre-axially, and concave post-axially; the fifth is bi-convex; the sixth is concave pre-axially, with a double post-axial convexity; the seventh has a double pre-axial concavity and a double convexity post-axially; the eighth has a double concavity at each end; the ninth has a double pre-axial convexity and a single one post-axially, and also curiously arched post-zygapophyses.

The ATLAS of man, in having no true body, agrees with that of all Vertebrates above the Ichthyopsida. In the highest member of that group, the Frog, the first vertebra has the neural arch attached to a centrum just as the other vertebræ have, and at the same time the power of rotation on the second vertebra is lost.

In having two articular surfaces for the skull, man's atlas differs from that of Birds and Reptiles, but agrees with that of Batrachians and some Fishes.

The total absence of articular processes is a character common to man's class, but in Birds and in some Reptiles (*e.g.* the Iguana) postzygapophyses are present.

The spinous tubercle may be enlarged into a distinct pointed process, as in some Baboons. The neural spine may be detached from the neural arcs, as in the Crocodile and Tunny. It may, as in the fish *Ephippus*, be separated from its centrum by the intrusion of the skull wall; the inferior tubercle may be drawn out into a long process, as in the Hare, or be doubled, as in the Duck-billed Platypus. Occasionally, as in

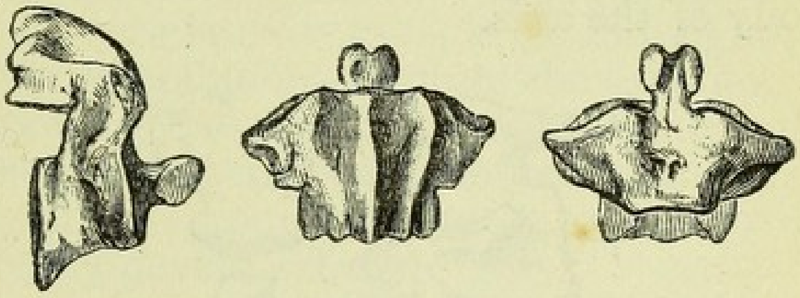

FIG. 67.—LATERAL, DORSAL, AND VENTRAL VIEW OF FIRST VERTEBRA OF *Amphiuma*.

Amphiuma, the body of the first vertebra may send out a process towards the head, reminding us of the odontoid process of the axis.

The slenderness of the neural arch and transverse processes is exceptional in man. The arch may be open medianly above, as in the Frog. The transverse process is expanded into a large plate in almost all beasts below Primates, but it may be short and imperforate, as in the common Fin Whale.

The canal for the vertebral artery is generally more complex (through increase of ossification) in beasts than in man, where indeed the osseous canal is simple. Transverse processes are also generally absent or rudimentary below Mammals, though the Crocodiles have them very long and rib-like.

The free condition of the atlas is not universal, as it is anchylosed to the axis in the Dolphin, and with all the other cervicals in the Right Whale. It may be fused in one solid mass with the skull, as in the Sturgeon, or with a certain number of succeeding vertebræ, as in the Rays. It may be firmly united by suture with both, as in the Ganoid fish *Bagrus* (see Fig. 61). The anterior base of the atlas may be unossified, as in the Wombat, or may remain a distinct bone, as in the Thylacine. The real nature of this part will appear shortly.

27. In its marked peculiarities the AXIS of man agrees with that of almost all Vertebrates above the Ichthyopsida, where it is indistinguishable. As we have seen, however, it may, as in many Cetaceans, not remain distinct; and even where it does remain distinct in them, the odontoid process is absent or very short.

In the coalescence of that process with the centrum, man agrees with the immense majority of his class; but in the Duck-billed Platypus it remains distinct as an *odontoid bone*, as it does also in many Reptiles (*e.g.* Crocodiles, Chelonians, and Lizards), where, however, it remains closely connected with the body of the axis.

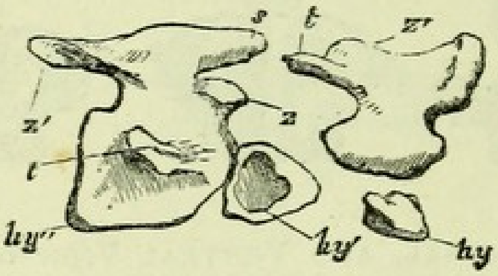

FIG. 68.—ATLAS AND AXIS VERTEBRÆ OF A CHELONIAN REPTILE.

hy, hypapophysis of atlas; *t*, transverse process; *z*, prezygapophysis; *z'*, post-zygapophysis; *s*, neural spine; *hy'*, odontoid bone; *hy''*, hypapophysis of true centrum of axis.

(*From the College of Surgeons' Museum.*)

The odontoid process may present a semi-cylindrical shape, as in the Sheep.

The slightly increased size of the neural spine of man's axis compared with those of his other cervical vertebræ, is but a faint indication of the great predominance it attains in many Mammals—arching forwards and backwards over three or four vertebræ. Its apex may be trifid, as in *Mycetes* and the Potto. Single or double hypapophysial processes may be developed, and the transverse process may be long and large, as in the Monotremes, where it (as a short and wide rib) remains for a considerable time distinct, and is attached to two superimposed transverse processes.

In its freedom the second vertebra varies in the way already indicated in describing the atlas.

28. The SIXTH cervical vertebra of man scarcely differs from the fifth, though the capitular root of the transverse process is slightly wider. This widening is a feeble indication of a marked and general mammalian condition, for (though not in the highest Apes) this root is usually much enlarged,

and forms a conspicuous plate, as *e.g.* in the Ox and Dog; and even in the Dolphin, where the cervical vertebræ are such thin plates of bone, the same root is suddenly enlarged.

In no animal but man does the spine of this vertebra ever bifurcate.

The SEVENTH vertebra sometimes in man has its transverse process imperforate, by the non-development of its capitular root. This condition, abnormal in him, is normal but not universal in the rest of his class. In other Mammals, as also in man, a short free rib may be attached to the transverse process of this vertebra; and where, as in the Three-toed Sloth, the number of vertebræ is nine, it is the eighth and ninth vertebræ which resemble in structure the sixth and seventh of man—thus showing that in this animal it really is the cervical vertebræ which are increased in number, and not that the condition has been produced by the first two dorsal ribs being imperfectly developed.

29. The coalescence and degradation which characterize the SACRAL VERTEBRÆ generally occur more or less in Vertebrates above the Ichthyopsida, which possess fully developed limbs.

The coalescence is generally less extensive than in man, though sometimes (as in Birds, some Edentates, and some Reptiles) it is much greater.

The sacrum of man is indeed a peculiar structure as regards the coexistence of characters each of which, taken separately, is shared by some or other members of his own class and order. The characters of which the coexistence is peculiar to him are: (1) The very marked sacro-vertebral angle. (2) The transverse and axial concavity of the ventral surface of the sacrum. (3) The concurrence of as many as five, or even six vertebræ in its formation—three of them generally contributing to form the auricular surface. (4) Its relative breadth, and the gradual way in which it narrows post-axially without any sudden contraction. (5) The large size of the foramina. (6) The small development of the spinous and other processes.

This region may, however, be more exceptional and peculiar than in man, as *e.g.* in the Rhea, where the vertebral interspace between the haunch bones is filled by a very narrow continuous ossification without a trace of division into vertebræ.

The sacrum of man may be looked at from two points of view, and it is very difficult to determine what parts really answer to it in many animals.

Thus: (A) it may be looked at with regard to its relation to the nerves which pass out through its foramina in front;[1] or, (B) with regard to the skeleton only, and this again from three other points of view: (1) with regard to the skeletal elements which comprise it; (2) with regard to its connexion with the hip-bones, and (3) with regard to the bony union of more or fewer vertebræ into one solid and complex mass.

The sacrum of nervous supply (*i.e.* as estimated by the destination of the nerves passing out through it) is much more constant than the purely osteological sacrum. It never probably embraces more than seven or less than two, perhaps rarely less than three vertebræ.

But while in man it is the two or three pre-axial sacral vertebræ which have distinct costal elements, and while a similar coexistence is probably universal in his class, very different conditions may possibly obtain when we descend further in the scale of animal life.

Thus, in Birds the sacrum of nervous supply appears in part to be made up of vertebræ which have no expanded sacral ribs, while large transverse processes are attached to the most post-axial vertebræ of the nervous sacrum.

The purely osteological sacrum is a very variable part with regard to all the three conditions above enumerated, varying even in the same species with the advance of age.

Man agrees with most if not all Mammals in having the more pre-axial part of his large sacral transverse process a distinct costal element. In Birds, however, the vertebræ of the sacrum which have expanded transverse processes, do not develop these from distinct ossifications. In lower forms (*e.g.* Crocodiles and Tailed-Batrachians) the sacral vertebræ have, on the contrary, a distinct and unmistakable rib attached to each transverse process.

As regards the extent of connexion between the osteological sacrum and the hip-bones, union is more extensive in man than in most beasts, or animals below Birds. Often in Mammals, and almost always in Tailed-Batrachians, it may be confined to a single vertebra. On the other hand, ten vertebræ may be involved in this union in Mammals, and twenty in Birds.

That part of the haunch-bone which we shall find is named the ilium, alone unites in Birds (Fig. 66, *il*) with this great number of vertebræ; but in man's class it only joins four

[1] As to the nerves, see Lesson VIII.

or five, though when that bony element which we shall find to be called the ischium also effects a bony union, the number may be raised to ten—as in some Armadillos.

When the osteological sacrum embraces as many as twenty (as in the Ostrich), then the lumbar vertebræ are encroached on by the extent of the hip-bones. Coccygeal vertebræ indeed may take an extensive share in it, as in some Edentates and Bats, where the osteological sacrum not only unites with the so-called ilium, but also anchyloses with the bone which is commonly termed the ischium.

The possession of a true osteological sacrum is a character man shares only with Vertebrates above Fishes. Very rarely, however, as in the Turbot, there is in Fishes even a kind of false sacrum, formed by the anchylosis of the bodies and ventral spines of the first two coccygeal vertebræ.

Compared with his own class only, man exhibits a sacrum which includes a number of vertebræ attained by few others, and but rarely exceeded, though sometimes there are six in the highest Apes. The number may reach eight, or even (as before said) ten in certain Armadillos; but this is the highest number of man's class, though about the smallest number found in the class of Birds, where, as we have seen, there may be as many as twenty.

Apart from union with the hip-bones, coccygeal vertebræ become anchylosed with the true sacrum in Mammals with the advance of age, so as to form altogether four or five sacral vertebræ. That the development of the sacrum is not always in proportion to that of the pelvic limbs, is proved by the little lizard *Seps*, in which, in spite of the rudimentary condition of the limbs, there are three sacral vertebræ. The sacro-vertebral angle is generally replaced by almost a straight line, and it is not nearly so marked in any Mammals as in man, except in some Baboons.

The concavity of its ventral surface, which is so variable in man himself, is generally much less marked in other Mammals, but sometimes it is quite as great, as in certain Baboons.

The tapering form of the sacrum of man is also exceptional, but it exists in the highest Apes, in Bears, and some other Mammals. Generally, however, in man's class the sacrum contracts suddenly at its post-axial end.

The wing-like processes (the sacral ribs) make it relatively wider than long in most Mammals.

The sacral spinous processes of man are but rudiments of what sometimes exist, as they are very long in Carnivora and others, and sometimes unite into a strong crest even in Primates, but especially in the Rhinoceros, some Ruminants, and Insectivora, e.g. *Sorex* and *Myogale*.

The lower end of the sacrum in man is devoid of processes, but in most forms there is a pair of strongly marked ones, which are most probably tubercular processes with annexed connate or developed ribs.

Metapophyses and anapophyses are hardly to be detected on the sacrum of man; but they are distinctly visible in many Mammals, even Monkeys.

The occasional open condition of the neural canal in man is very exceptional, being repeated only in the highest Apes.

That the sacrum has a flat articular surface at one end for the last lumbar vertebra, and at the other for the coccyx, is the normal condition, but the vertebræ composing it may, as in Batrachians (e.g. *Menopoma* and *Cryptobranchus*), be convex in front and concave behind. It may, however, present a condition such that its two component vertebræ have the conjoined surfaces of their centra flat, and the other surfaces respectively concave, as in Crocodiles.

30. No better example of the inadequacy of the exclusive study of man for a full comprehension of his frame can probably be given than the human os coccygis.

The anthropotomist, though he would readily perceive that it was the rudimentary representative of a tail, would yet never suspect to what diverse and curious structures it corresponds.

Indeed, the COCCYGEAL REGION of the vertebral column, instead of only varying as to the size and number of its parts, is the subject of very peculiar modifications of structure, and of unexpected modes of ossification and development.

It may act as an extra hand; it may be the main or exclusive locomotive organ; it may, together with the neck, contain the only free vertebræ of the body; or it may be still more reduced and rudimentary than in man.

It may in part consist of a solid bone formed by the fusion of primitively separate vertebræ, or it may be distinguished from the rest of the vertebral column as the only portion never made up of separate vertebræ at any time of life.

The three, four, or five coccygeal vertebræ of man may be represented by as many as forty-six in his own class—namely, in the long-tailed Pangolin or Manis; and in his own order it may reach the number thirty-three, as in the pre-eminently arboreal Spider Monkeys, which have the tail prehensile, serving as an additional hand. It may, on the contrary, in his own order, be reduced to three bones, as sometimes in the Magot (*Inuus*).

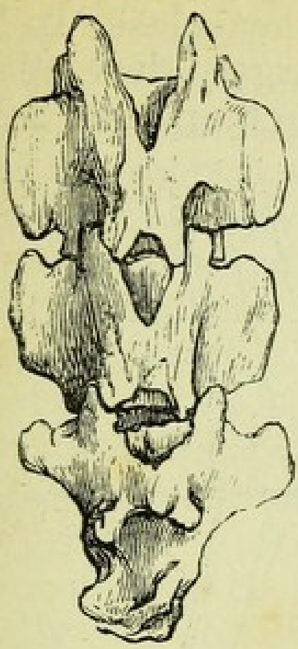

FIG. 69.—CAUDAL VERTEBRÆ OF *Inuus*.

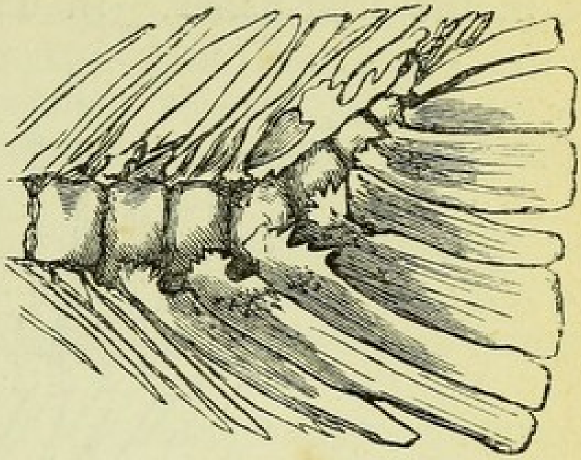

FIG. 70.—POST-AXIAL TERMINATION OF THE VERTEBRAL COLUMN IN A SALMON.

(*From Specimens in the British Museum.*)

It is in aquatic forms that the tail attains the greatest relative bulk, and in some Sharks may contain the prodigious number of 270 vertebræ.

It is in the Tortoises that we find the tail supported by the only free vertebræ which are not cervical, all those of the trunk being immovably united with the ribs and with the dermal bony plates forming altogether the shell, or carapace.

The maximum of degradation and abortion of the coccyx is in the Bats, where coccygeal vertebræ may be reduced to two.

The coccyx of birds generally consists of from six to eight vertebræ, but may have ten. At its end is a so-called ploughshare-bone, consisting of two or more anchylosed vertebræ.

The peculiar coccyx of the Frog never consists of distinct vertebræ at any time of life, but is formed by the ossification of the membrane which surrounds the notochord, to which two small neural arches become attached.

In osseous Fishes the end of the tail is turned up and remains persistently as a cartilaginous rudiment at the end of the vertebral column, generally hidden and enclosed by special bony plates.

In the higher animals provided with numerous coccygeal vertebræ, these vertebræ are often provided with processes and articulations as complex as those of vertebræ more anteriorly situate. Pre- and post-zygapophyses, anterior and posterior transverse processes, metapophyses, neural arch and neural spine, together with hypapophysial processes or arches (chevron bones), may be present in man's own class. In Fishes the hypapophysial parts may be very largely developed, as, *e.g.*, in the Flat-fishes. In Tailed-Batrachians, the anterior

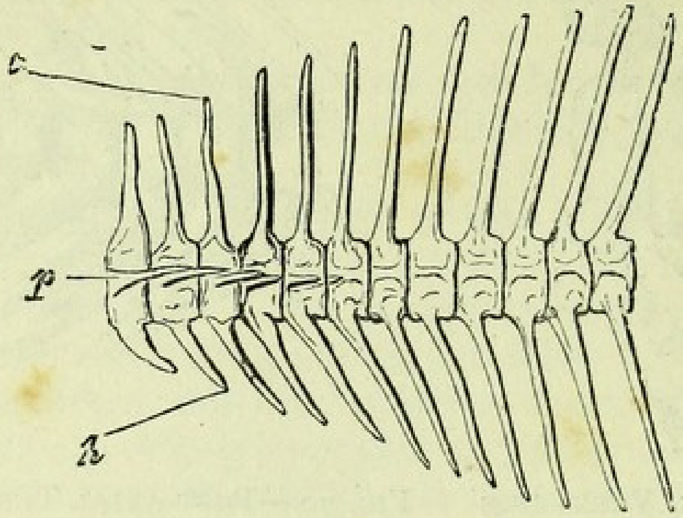

FIG. 71.—PART OF THE VERTEBRAL COLUMN OF A SOLE.

n, neural spines; *p*, transverse processes; *h*, hypapophyses.

coccygeal vertebræ (*e.g.* in *Menobranchus*) may be furnished with true ribs, supported by both tubercular and capitular transverse processes, in addition to articular, neural, and hypapophysial parts.

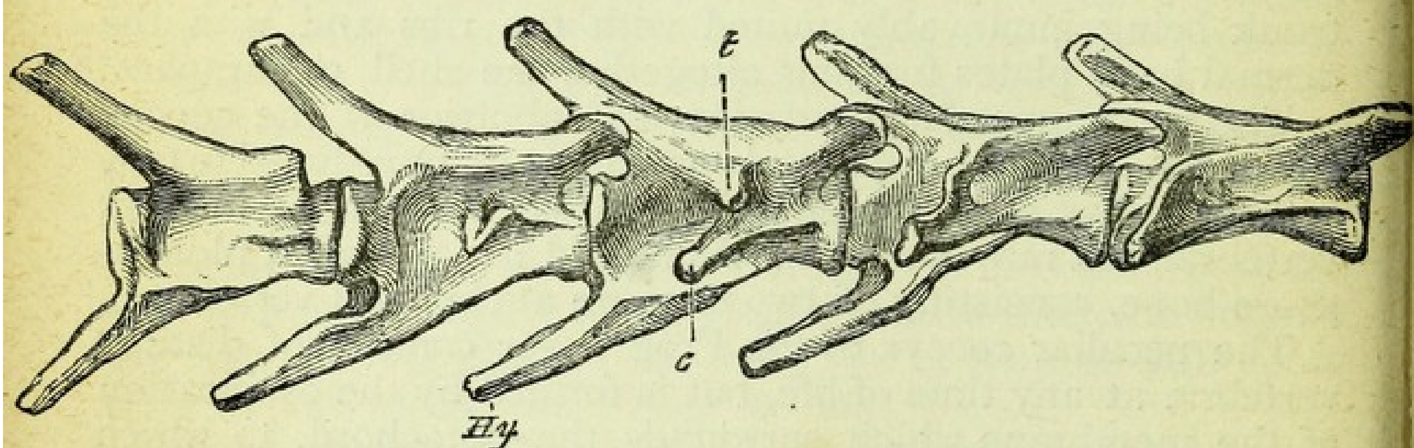

FIG. 72.—LATERAL VIEW OF THE FIVE MOST PRE-AXIAL CAUDAL VERTEBRÆ OF MENOBRANCHUS.

t, tubercular process; *c*, capitular process; *hy*, hypapophysis.

The downwardly tapering condition of the coccygeal vertebræ which exists in man is the general condition of such parts; but sometimes, as in the little Armadillo *Chlamydophorus*, the transverse processes increase in size instead of decreasing in that direction.

In lower forms, *e.g.* Tailed-Batrachians and Fishes, the inferior (hypapophysial) arches sometimes develop articular processes or parts simulating such.

31. The beautiful sigmoid curvature of the VERTEBRAL COLUMN of man (Fig. 38) is, in its perfection, absolutely peculiar to him, though some of the Apes (not the highest, but the Baboons—*Cynocephali*) approximate to him in this respect. This exceptional condition of structure in man is related to his exceptional (erect) attitude.

As exceptional a curvature, though a very different one, may exist. This is shown by Bats, where the hinder part of the spine bends sharply forwards as a quadrant, bringing the pelvis very much in front.

The gradual thickening of the spinal axis from its cranial end downwards to the sacrum, is a condition which obtains generally in Vertebrates, except Fishes, Bats, and those extinct flying Saurians the Pterodactyles, in which that axis gradually decreases in bulk tailwards.

The post-axial projection of the neural spines, especially those of the posterior cervical and anterior dorsal vertebræ, is considerably less in man than in most animals of his class, though considerably greater than in some—*e.g.* the Hedgehog. On the other hand, neural spines attain in many Fishes (*e.g.* the Sole, Turbot, &c.) a prolongation compared with the size of the spinal axis vastly exceeding anything to be found even in the marine (Cetacean) members of the class to which man belongs.

32. The mode of OSSIFICATION of the vertebræ of man agrees with that which exists generally in his class, most of the vertebræ ossifying from one point in the body and one other point in each neural arch—besides from the epiphyses, where these exist.

The line of junction of the lateral (neural) pieces with the central piece is termed the neuro-central suture, and in most Mammals, as in man, it is so disposed that each lateral piece contributes to form a portion of the body. This is not, however, universally the case, as in the Whale order the suture is placed more dorsally, so that the central ossification forms not only all the centrum, but also more or less of each lateral piece.

Just as in man, so in other members of his class, separate ossifications often indicate costal elements in the cervical, lumbar, and sacral regions.

The fact, however, of a part being ossified by the extension into it of a neighbouring ossification (when it is said to be exogenous[1]), or by an independent centre (when it is said to be autogenous[2]), constitutes but a very secondary and unim-

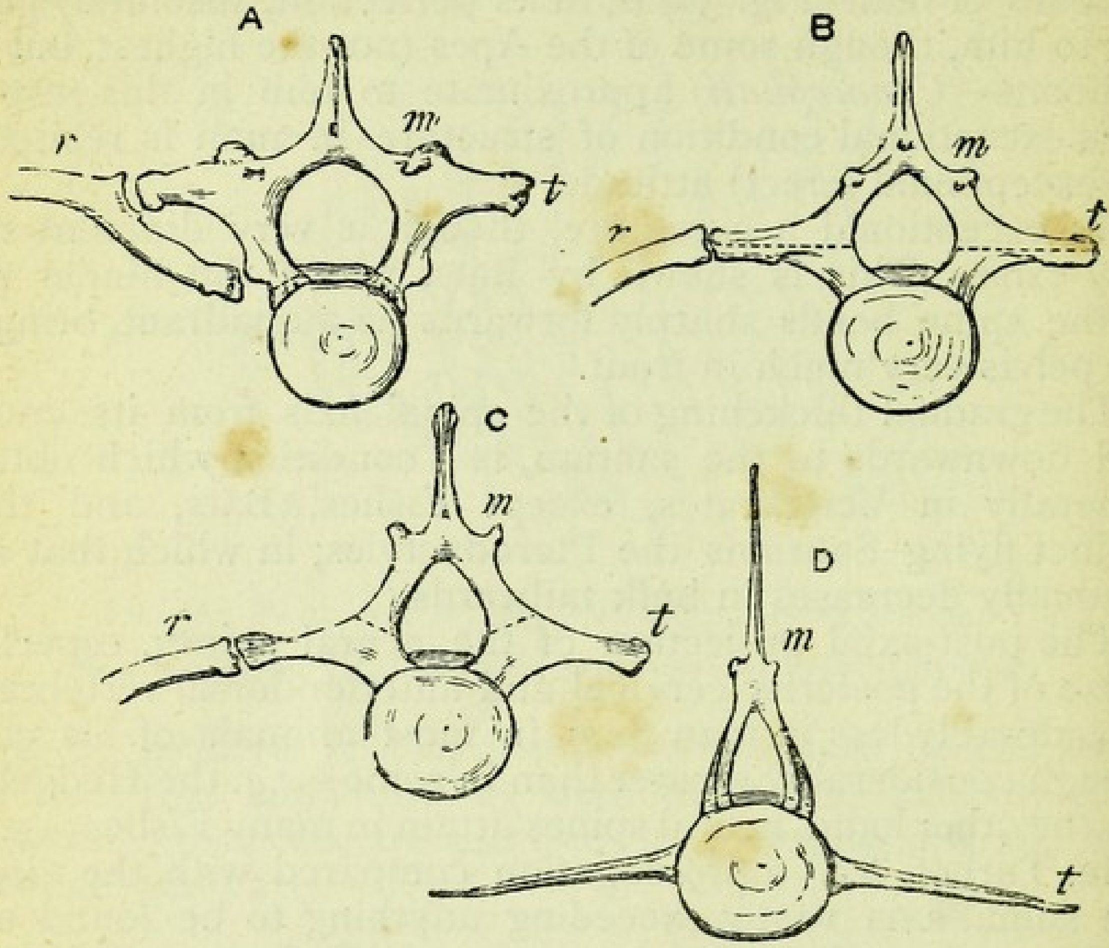

FIG. 73.—ANTERIOR SURFACE OF VERTEBRÆ OF DOLPHIN (*Globiocephalus melas*).

A, fifth thoracic; B, seventh thoracic; C, eighth thoracic; D, first lumbar; *r*, rib; *m*, metapophysis; *t*, transverse process. The dotted lines indicate the position of the neuro-central suture.

(*From Prof. Flower's "Osteology."*)

portant distinction; since neural arches (as in the tail of the Dog) or neural spines (as in trunk vertebræ of some Ungulates) may ossify in either mode.

In the same way, transverse processes, both capitular and tubercular, may be formed by outgrowths of the central ossification only, or by extensions of the lateral ossification, or by the concurrence of both these parts, as in Plesiosauria and some Cetacea (see Fig. 73).

The presence of epiphyses on each side of the body and at the tips of the neural spines, transverse processes, and meta-

1 From ἔξω, outside, and γενέσθαι, to arise.
2 From αὐτός, self, and γενέσθαι.

pophyses, is a character common to most animals of man's class, but the centrum does not appear to have epiphyses in the Sirenia, Monotremata, and in the animals below the mammalian class.

In those Mammals which have chevron-bones there are, of course, ossifications which do not exist in man.

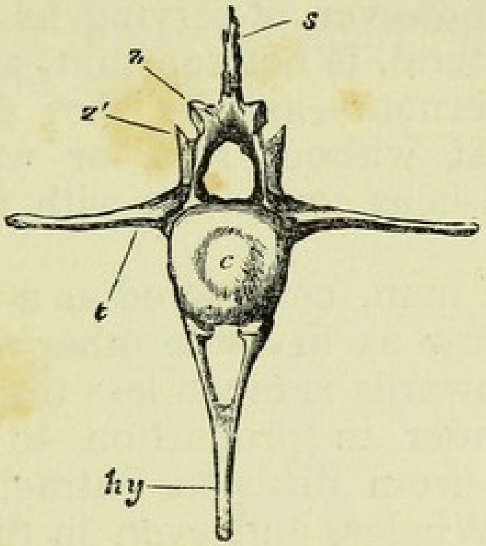

FIG. 74.—CAUDAL VERTEBRA OF A CROCODILE.

c, centrum ; *s*, neural spine ; *t*, transverse process ; *z*, pre-zygapophysis ; *z'*, post-zygapophysis ; *hy*, hypapophysis, or "chevron-bone."

In the lower Vertebrata the vertebral bodies may be at first formed by superficial ring-like ossifications, as in many Fishes ; and in some, as in the Carp, distinct lateral ossifications may exist, one on each side of the centrum.

The walls of the two concave vertebral, articular cups may ossify, making an hour-glass-shaped ossification, to which concentric or radiating lamellæ may be added, as in certain Sharks.

Cortical ossifications (*i.e.* of the fibrous sheath of the notochord) may appear and coalesce with vertebræ, as in the coccygeal vertebræ of the Frog.

Sometimes, as in *Lepidosiren*, bony neural arches may be formed, and more or less embrace a permanently soft and unossified chorda dorsalis.

33. A bony case, like the THORAX of man, exists in all Beasts and Birds, without exception. It also generally exists in Reptiles, but is strangely modified in serpent-like Lizards, and in Tortoises. In the former it is enormously drawn out, and made imperfect below by the small development of a sternum. In the latter it attains a maximum of solidity, and enters into bony union with the dermal skeleton.

A thorax is not a constant character of Vertebrates, for it cannot be said to exist in those Batrachians which have no ribs, neither in true Serpents nor in Fishes, both these groups of animals being utterly destitute of a sternum.

34. The STERNUM of man represents a part constantly present in limbed Vertebrates above Fishes, except Chelonians, as also in some forms in which the limbs are absent. Its human condition, however, of serving as a ventral abutment to ribs, though general, is not constant, as not only may ribs exist without a sternum—as in Fishes and Serpents—but a sternum may exist without ribs, or without forming any cartilaginous or osseous connexion with ribs, as in the class Batrachia.

The sternum of man, considered as a whole, is neither so broad nor so narrow as in some other forms, and its depth from the surface inwards is much less than may obtain.

Thus it is broader in proportion to its length in most oviparous animals (from Birds to Batrachians), also in some Mammals, as the Whales, and even in the Siamang Gibbon, belonging to man's own order. In most members of man's own order, however, and in very many of his class, it is, as in the Dog, and in some Reptiles (as the Crocodile and Chameleon), much more narrow in proportion to its length.

The above exception as to Chelonians not having a sternum may well excite surprise, for Tortoises and Turtles have not only well-developed limbs, but it has been commonly supposed that part of their "shell," the great ventral shield (or plastron), is one great sternum, or at least a sternum with dermal ossifications added. It appears, however, that this great complex plate does not really include a sternum.

That threefold division of the sternum which exists in man is normal in his class. In Birds and Reptiles it also exists, though more obscured and difficult to define.

Even in Mammals, however, this threefold division is not universal, as (*e.g.* in the Greenland Whale) only the manubrium may exist, the rest of the sternum aborting; while in the Dugong we have a xiphisternum (the representative of the xiphoid process of man), together with a manubrium, but no ossified representative of the middle part of the sternum.

In Tailed-Batrachians and the Slow-worm (*Anguis*) we have a simple sternum which cannot be said with certainty to represent any one of the three divisions; while in many Frogs and Toads we have a middle and xiphoid sternum, as also in many Reptiles, and we have all three (as before said) in some Reptiles (*e.g.* the Crocodile and Chameleon) and in Birds.

The manubrium forms a much larger part of the sternum in some members of man's class than it does in him, as is the case in the Cetacea, the Monotremes, and in the Mole, where its relative length about equals that of all the rest of the sternum.

On the other hand, it may be remarkably small and narrow, as in the Pig and the Horse.

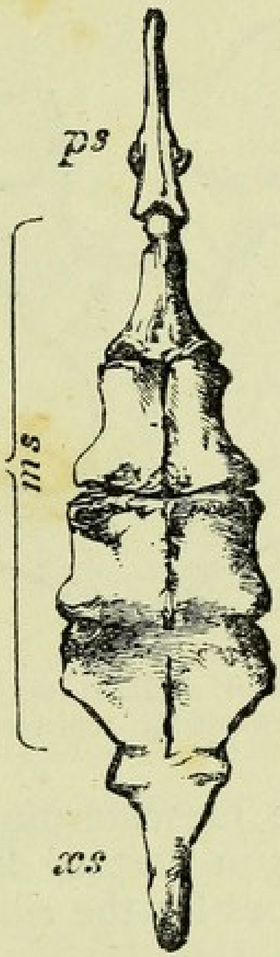

FIG. 75.—STERNUM OF THE PIG (*Sus scrofa*).
ps, manubrium, or pre-sternum ; *ms*, middle part of the sternum, or mesosternum ; *xs*, xiphisternum.
(*From Professor Flower's "Osteology."*)

Sometimes this part may develop a strong median keel for muscular attachment, as in Bats, the Mole, and Armadillos. This keel, however, does not answer to the keel of Birds, which belongs to the more post-axial part of the sternum.

The "episternal granules" occasionally present in man are replaced in some Mammals by considerable horn-like processes, as in the Howling Monkeys (*Mycetes*) and Mice.

The manubrium may be remarkably small when coexisting with a sternum hypertrophied in other parts, as in Birds.

F

The middle part of the sternum (*mesosternum*) may be much shorter relatively than in man, as is the case in the Sperm Whale, and it may abort, as just said, in the Dugong. Generally, however, in Mammals it is large and more permanently segmented than in him, and may (as in the Orang) show to a much later period its median division. The division into two lateral halves (one piece on each side only) transitorily exists in the Struthious Birds.

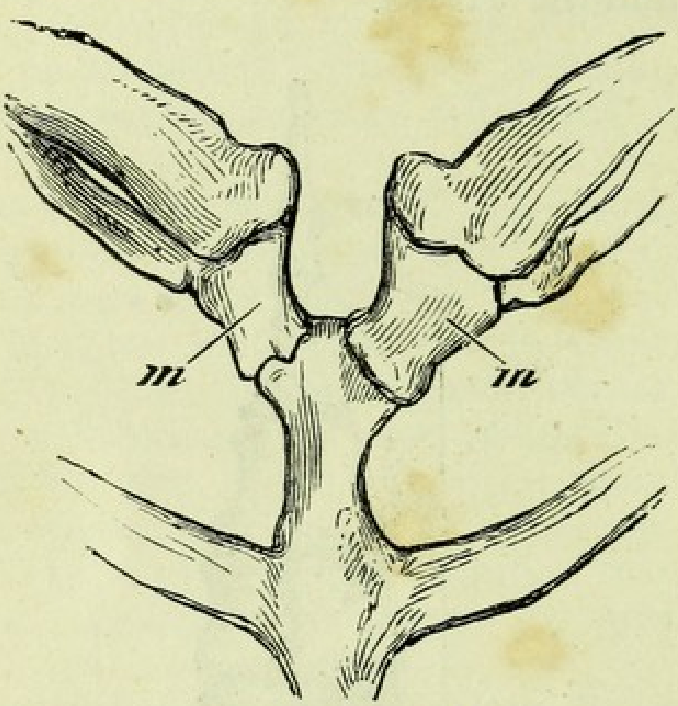

FIG. 76.—STERNUM OF A HOWLING MONKEY (*Mycetes*). *m*, bones representing "episternal granules."

The segments of the mesosternum may send down processes together forming a sort of keel, and each furnished with two articular surfaces for the ribs, as is the case in the Tamandua Ant-eater.

The xiphoid cartilage, or its osseous or cartilaginous representative, may abort altogether as a distinct part, as in the Tailed-Batrachians and the Right Whale. It may be long and pointed, as in the Two-toed Ant-eater, or enlarged and rounded, as in very many species (e.g. *Sorex*). It may even in Mammals be enormously produced into two elongated horns, far exceeding all the rest of the sternum in size, as in the long-tailed Pangolin; and a similar but more reduced form may exist in Lizards (e.g. *Iguana*, *Draco* (Fig. 78), and still more *Stellio*).

It is in Birds, however, that the xiphisternum attains its maximum of size and importance, forming all that part of the sternum post-axial to the attachment of the ribs. It may consist of one sheet (as in the Ostrich and Cassowary), or be divided into a median and two lateral processes, one on each side (as in the Apteryx); or into a median process and four lateral ones—there being an internal and external xiphoid process on each side of the median one—as in very many birds (*e.g.* gallinaceous birds, such as the Fowl and Pheasant). This median process it is which bears the keel, or the greater part of the keel, in Birds.

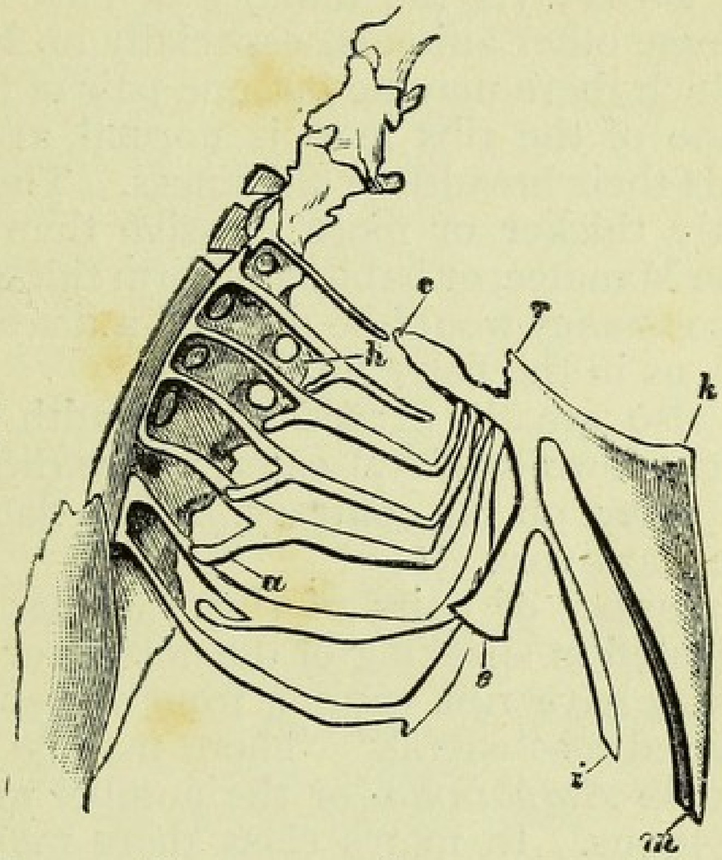

FIG. 77.—THORAX OF A GALLINACEOUS BIRD.

k, keel of entro-sternum; *m*, middle xiphoid process; *i*, intermediate xiphoid process; *e*, external xiphoid process; *r*, rostrum; *c*, costal process; *h*, hypapophysis; *a*, appendage from ribs, or *uncinate process.*

In certain animals (*e.g.* the Monotremes) there is a median ossicle in front of the manubrium, which is often called the episternum. This really forms part of the appendicular skeleton, being a portion of the shoulder structure. It will therefore be noticed under that head.

35. In possessing RIBS (that is, distinct osseous or cartilaginous parts attached at one end to the vertebral column, and tending to surround the body cavity) man agrees with the immense majority of other Vertebrates. Some, however, as the Frogs and Toads, have none, nor can any be said to exist in some of the lowest Fishes, *e.g.* the Lamprey and its allies.

In the division of the ribs into two categories, the "true" and the "false" ribs, man agrees with all animals which have ribs at all, except Serpents, Fishes, and Chelonians; Serpents having many ribs indeed, Fishes few or many, and Chelonians few, but all having no sternum, so that every rib must be reckoned to be a false rib in them—and this in spite of their fixity in Tortoises.

In the proportion of true to false ribs man occupies an intermediate position. Thus the number of true ribs is more in excess in some other animals than in him, as *e.g.* in the Seals, and in Birds; yet the number of false ribs is greatly in excess in some other animals, especially in the Whalebone Whales, in which there may be but one pair of true ribs.

In the shape of the ribs man is normal, and their length always exceeds their breadth or thickness. They may, however, be vastly thicker or more massive than in him, as is the case in the Manatee, or habitually form thickenings which but for their constancy would be deemed a diseased condition (pathological), as in the fish *Platax*.

They may also greatly exceed the breadth possessed by man's, as in the Two-toed Ant-eater, where they overlap one another; they may, on the contrary, be less flattened than in him, as in the Carnivora.

As to the number of pairs of ribs, this has already been generally indicated in speaking of the dorsal vertebræ, though in Birds we may have ribs coming from vertebræ which are generally counted as "sacral." There may be as few as five or six pairs, as in *Amphiuma*, or the number may reach 320, as in some Pythons. In man's class there may be as many as twenty-four pairs, as in the Two-toed Sloth, or as few as nine, as in the Hyperoodon.

In the fact that ribs (distinct and articulated) are confined to the dorsal region, man agrees with most Vertebrates. Such ribs, however (more or less free and more or less long), may exist in the cervical region, as we see in the Crocodile and in many Reptiles; in the so-called "sacral" region, as we see in Birds; and even in the caudal regions, as we see in Menobranchus. Of such ribs, however, enough has been said in treating of those regions of the spine.

The function of aiding respiration is one which the ribs possess in the higher Vertebrata, but quite other purposes may be subserved by them in addition to, or instead of, respiratory action. Thus certain ribs, by excessive elongation, may support a flying membrane, as in the Flying Dragon, or by their sudden erection expand the skin of the neck, as in the Cobra.

Terrestrial locomotion may also be due to these parts, as in

Snakes, which glide along by the successive application to the ground of the edges of ventral horny plates, each plate being attached to the ends of a pair of ribs. There being no sternum in Serpents, all the ribs are, as before said, "false;" but all the ribs may also be false notwithstanding the presence of a sternum, as in Tailed-Batrachians.

The ribs may form a solid case for the protection of all the other parts. Thus in Tortoises the head and limbs can be drawn into such a case (called the carapace), which is formed of greatly expanded ribs joining each other, and also the expanded neural spines before noticed, by suture (Fig. 57).

In man we find the floating ribs float by their anterior ends only, their hinder ends articulating with the vertebræ. The very reverse condition to this may appear to obtain, as in the Crocodile, where we have ventral rib-like structures (towards the hinder end of the abdomen), which are attached ventrally, but are free at their vertebral ends, and thus float in the reverse direction. These, however, are hardly true ribs, but are ossifications of a more superficial region.

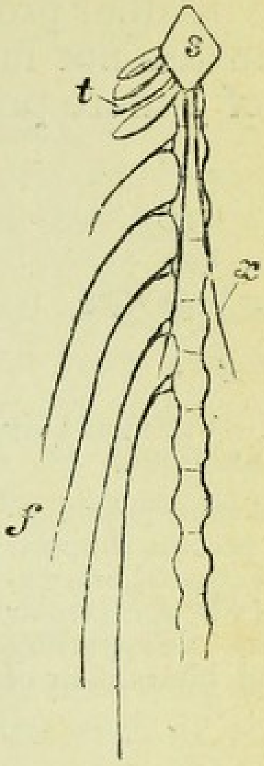

FIG. 78.—RIBS OF THE FLYING LIZARD (*Draco volans*).

s, sternum; *x*, one of the diverging branches of the xiphoid process; *t*, true ribs; *f*, floating ribs.

The presence in the ribs of a distinct "head" and "tubercle," as in man, is a very general but not a constant character. Very often, however, if not always, when there is but one articular surface for attachment to the vertebral column, that surface represents and is equivalent to a "head" and "tubercle," as it were, united and fused together; though in Monotremes the ribs are attached only to the sides of the bodies of the vertebræ.

This gradual fusion is well shown in the different vertebræ of the Crocodile, where, as we proceed post-axially, these two parts become more and more approximated together.

As in man, so generally, it is at the more pre-axial part of the series of ribs that this distinction into head and tubercle is most marked.

In the Whalebone Whales after the first few ribs the "heads" and "necks" entirely disappear, the more post-axial ribs being attached by their "tubercles" only.

The peculiar proportions of the head and tubercle of the ribs in man are not universal, but seem to be special modifications of a more primitive type, such as exists in the Ichthyosaurus and in some Tailed-Batrachians. In them the rib divides at its proximal end into two diverging and equal processes, the upper of which (answering to the tubercle of man) articulates with the dorsal, or tubercular, transverse process, while the lower (answering to the neck and head of man's rib) articulates with the ventral, or capitular, transverse process. In some other Tailed-Batrachians the proximal end of the rib bears a double facet, and articulates with a similarly facetted transverse process, which thus evidently answers to an upper and a lower transverse process united into one.

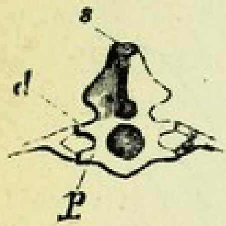

FIG. 79.—VERTEBRA OF AXOLOTL.

s, neural spine; *d*, tubercular process supporting the dorsal bifurcation of rib; *p*, capitular process supporting ventral bifurcation of rib.

The relation borne by these articular surfaces to the neuro-central suture is not constant. Sometimes, as in man, the "head" articulates mainly above that suture; sometimes, as in Monotremes, altogether below it. In *Ichthyosaurus* both surfaces are attached altogether below that junction, while in *Plesiosaurus* the point of attachment rises as we proceed backwards.

The class of Fishes shows what abnormalities are possible with respect to the modes of attachment of the ribs, as in *Batrachus* they have a more and more dorsal origin, until, at the anterior end of the body, they are actually attached to the neural spines!

That double attachment which exists in man between the proximal end of the rib and *two* vertebræ is not universal. Thus in Birds it is only the last rib, or the last but one, which is attached to the point of junction of two adjacent vertebral bodies.

The greater breadth of the first rib of man is a character frequently found in his class and sometimes much exaggerated, as in the Great Armadillo. Often in Mammals, and in lower forms generally, it is only of similar breadth to those post-axial to it.

The greater curvature in man of the first rib is a character he shares with some animals (*e.g.* Apes and Cetaceans), though sometimes, as in the Ungulata, it (as well as the second rib) is almost straight.

Occasionally, as in the Guinea Pig, Rhinoceros, and others, the first rib bears a little spinous tubercle for the attachment of the scalenus muscle.

The ribs may consist not only of two parts, as in man, but may have a third part intercalated between each vertebral rib and its sternal cartilage or rib, as in the Monotremes, Crocodiles, and many Lizards.

The vertebral rib may give off (Fig. 77, *a*) a post-axially projecting process (called *uncinate*), which may ossify as a distinct bone, as is the case in most Birds and in the Crocodile.

The sternal ribs may be cartilaginous or they may be completely osseous. The latter, *e.g.*, is the case in Birds and the Armadillos.

In shape they may differ much from man's, expanding greatly, as is the case in the Great Armadillo and the Monotremes. Each sternal rib may be set at a very marked angle with its vertebral rib, as in Birds, instead of more or less continuing its curve, as in man.

Some of the sternal ribs may pass into each other (on the ventral aspect of the body) directly without the intervention of a sternum, or run right into the substance of the sternum, as is the case with the more post-axial ribs of Chameleons and some other Lizards.

The sternal ribs may even slightly bifurcate at their ends, as in the Tamandua.

Bony sternal ribs may have, at their dorsal ends, synovial articulations with the vertebral ribs, and also synovial articulations with the sternum at their ventral ends, as in Birds.

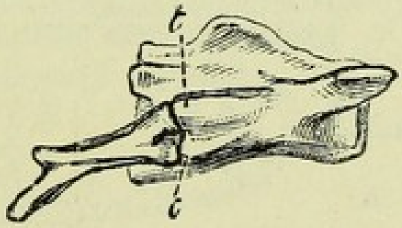

FIG. 80.—LATERAL VIEW OF SIXTH VERTEBRA OF SALAMANDRA.
t, tubercular process; *c*, capitular process—the two supporting a rib which bifurcates at its free, distal end.

The ribs may consist of single bones only, without any division into vertebral and sternal portions, as in Fishes and Batrachians. Ribs may also bifurcate distally, as in some of the two last-mentioned classes (e.g. *Salamandra*); and lastly, there may be two distinct series of ribs on each side of the body, one series being dorsally situate with regard to the other. This condition is found in many Fishes, as *e.g.* the Tunny and *Polypterus*, and in the latter some vertebræ have four ribs on each side springing from the doubled transverse process before noticed (Fig. 52).

36. That mode of DEVELOPMENT of the vertebral column which we have seen to take place in man, takes place also, broadly speaking, in all Vertebrates; only the process is arrested at different stages in different forms. Thus the notochord may, as we have seen, persist, or the ossification of the vertebræ break off at various stages, leaving a great deal or only a rudiment of the notochord persisting.

The process of consolidation and union may proceed only so far as to leave transverse processes distinct, *e.g.* the Carp, or neurapophyses in two or four pieces, and separate from the neural spines, as before noted.

Finally, not only may vertebræ be found denser than those of man, as the vertebræ of Serpents, but coalescence may extend to adjacent vertebræ in the several ways already described.

Our survey shows us that the backbone alone, without the help of any limb, may serve as an organ for creeping over the ground or swimming through water, for climbing trees, for crushing prey as in the Boa Constrictor, and even as a hand to present food to the mouth as also in the Boa, or to grasp and bring near small detached objects, as is done by the tail of the Spider Monkey.

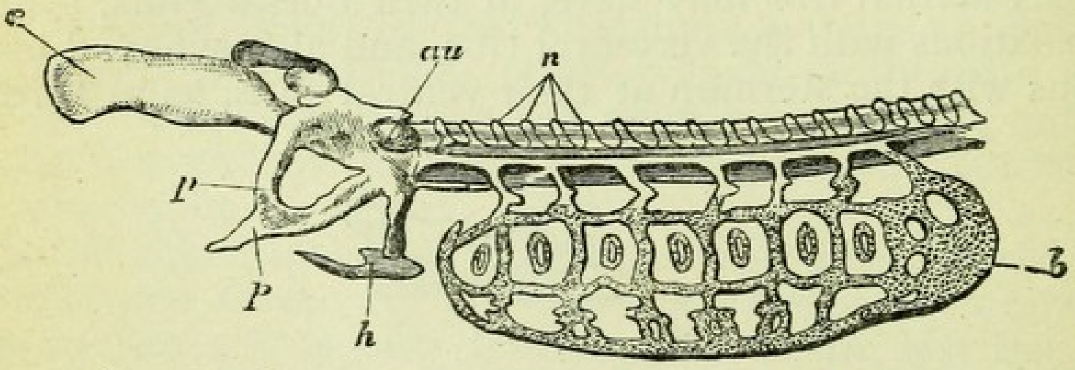

FIG. 81.—SKELETON OF HEAD AND GILLS OF LAMPREY.
b, cartilaginous basket; *n*, neural laminæ. (For the parts of the skull see Lesson III.)

An exceptional structure which probably belongs to the same skeletal category as the ribs and sternum may here be mentioned. This is the cartilaginous "basket" which supports the gills in the Lamprey. It consists of arcs of cartilage which descend (the spine being horizontal) on each side from the soft representative of the backbone, and are connected by transverse bars extending in the direction of the spine. The hindermost (most post-axial) ventral part of this basket supports the heart.

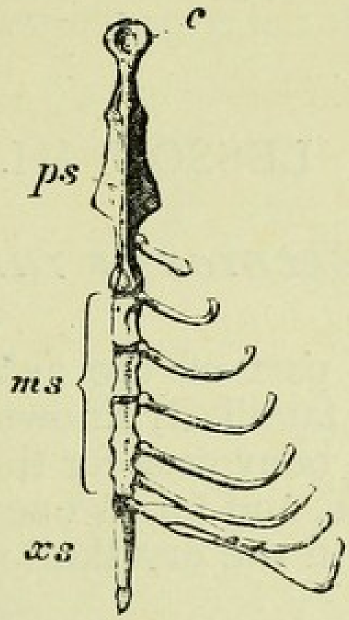

FIG. 82.—STERNUM OF COMMON MOLE (*Talpa europæa*).
ps, manubrium; *ms*, mesosternum; *xs*, xiphisternum; *c*, point of attachment of the clavicle.
(*From Professor Flower's "Osteology."*)

In some Sharks there are similar cartilaginous arcs (though much less developed) supporting the external borders of the partitions between the gills.

LESSON III.

THE SKELETON OF THE HEAD.

1. THE remaining part of the axial endoskeleton is the skeleton of the head, familiarly known as THE SKULL.

This large rounded bony case for the brain is also the seat of the organs of sense, and forms one coherent mass, except the lower jaw, which in the dry skull readily falls away from the rest.

Neglecting for the present this lower jaw—or, as it is called in zootomy, *mandible*—the rest of the skull is rounded behind and above, and more or less flattened in front, below, and at the sides. Behind and above, it presents a pretty smooth and even surface, crossed by those undulating, interdigitating lines of bony union spoken of in the last Lesson as *sutures.*

When sections are made it is seen that the rounded portion forms the roof and hinder boundary of the great cavity in which is lodged the brain, and that irregular bony prominences are placed below the front part of that cavity. The skull then may be roughly divided into—

(1) The brain-case, skull proper, or Calvarium.[1]

(2) The skeleton of the face.

Certain conspicuous openings and prominences occur in different regions.

The projecting part of the back of the head is termed the *occiput,* and beneath it is a large hole, looking downwards, termed the *occipital foramen.* On each side of the front part of this hole is a rounded projection, and these projections, termed occipital *condyles,* articulate with the cup-shaped hollows on the upper side of the atlas vertebra (see Fig. 89).

Thus the margins of this foramen coincide with the neural arch of the atlas vertebra, and the interior of the skull forms the expanded summit of the vertebral neural canal; indeed

[1] From *calva,* the skull.

the brain and spinal marrow are connected and become continuous through this occipital foramen.

If the skull be turned base upwards, a strong bluntly pointed prominence will be seen to project from each outer margin on a line passing from right to left through the occipital condyles. The prominence is called, from its shape, the mastoid [1] process.

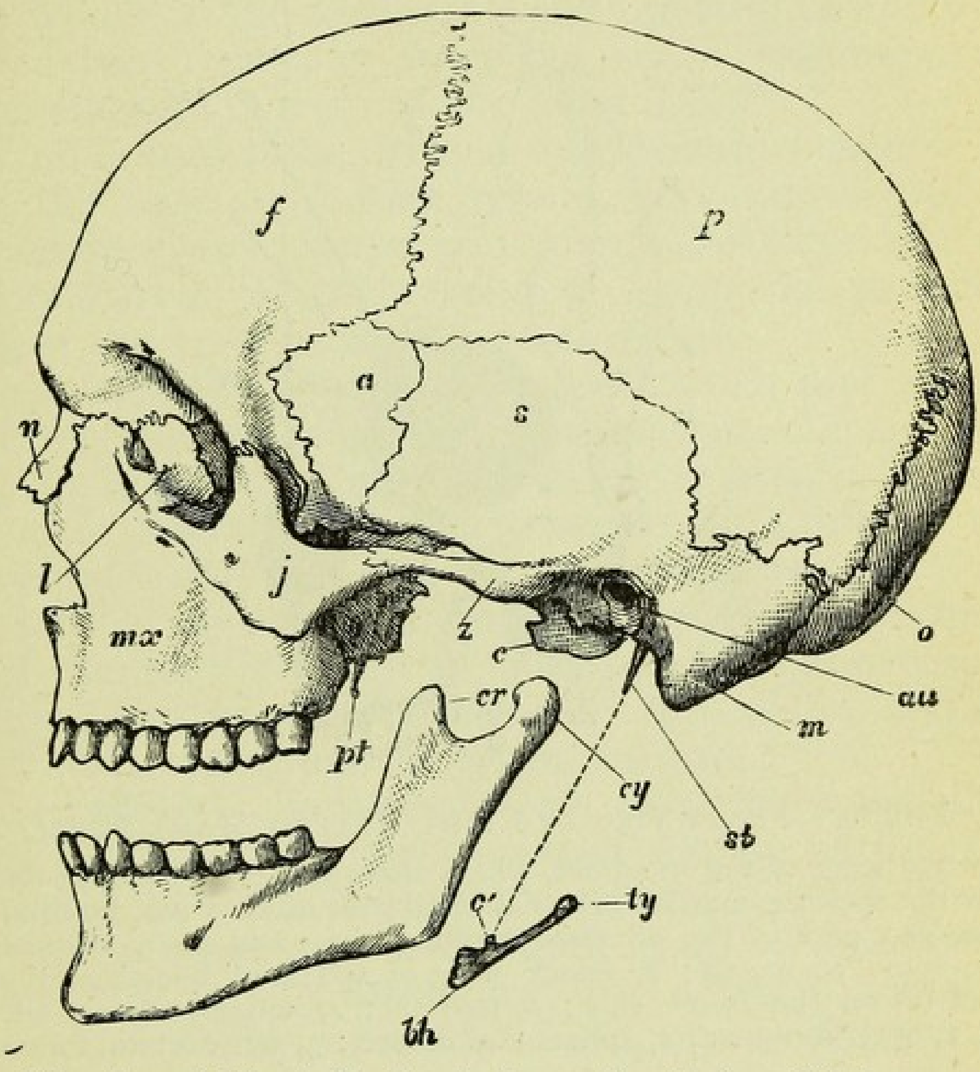

FIG. 83.—Side view of Man's Skull—the lower jaw being slightly removed, and the line of ligamentous attachment of the hyoid represented by a dotted line.
a, greater wing of the sphenoid bone ; *au*, opening of external auditory meatus ; *bh*, body of the hyoid ; *c*, an occipital condyle ; *c'*, corniculum of hyoid ; *cr*, coronoid process ; *cy*, condyle of the lower jaw ; *f*, frontal bone ; *j*, malar ; *l*, lachrymal ; *m*, mastoid process ; *mx*, maxillary bone ; *n*, nasal bone ; *o*, occipital bone ; *p*, parietal ; *pt*, internal pterygoid process ; *s*, squamous part of the temporal bone ; *st*, styloid process (connected by a dotted line with corniculum of hyoid) ; *ty*, greater cornu of hyoid ; *z*, zygomatic process of temporal bone.

The under surface of the face (formed by the bones of the roof of the mouth) lies at a different level from that of the base of the skull proper. Connecting these two surfaces there are on each side a pair of vertical bony plates termed

[1] From μάστος, a nipple.

alæ, or wings, and between the two pairs are a pair of large openings separated by a median partition and directed backwards. These openings are the hinder nostrils, or *posterior nares.* At each side of the skull, behind the orbit, is to be seen an arch of bone—a sort of flying buttress connecting the skull and face together, and termed the zygoma.[1]

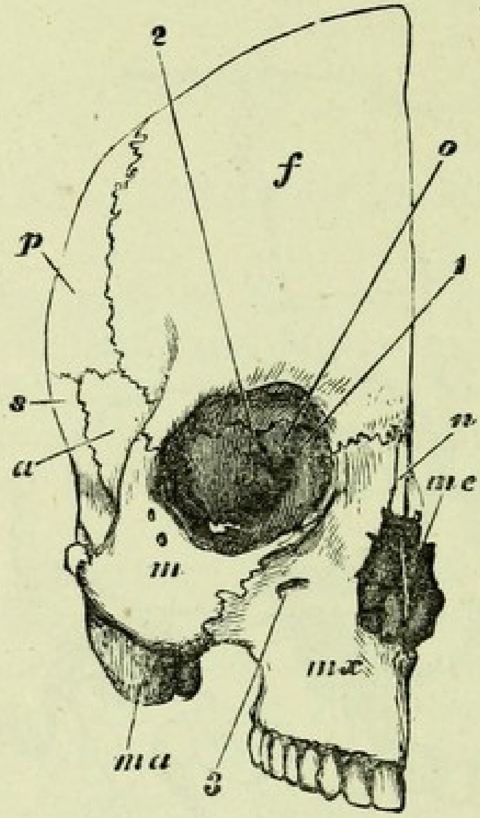

FIG. 84.—FRONT VIEW OF RIGHT HALF OF MAN'S SKULL.

a, the greater wing of the sphenoid, which also appears in the orbit on the *outer* side of the opening marked (2); *f*, frontal; *m*, malar; *ma*, mastoid process; *me*, median part of the ethmoid dividing the nasal fossa vertically in the middle line; *n*, nasals; *o*, lesser wing of sphenoid bounding the opening marked (2) on the *inner* side; *p*, parietal; *s*, squamous part of temporal bone; 1, optic foramen; 2, sphenoidal fissure; 3, infra-orbital foramen.

When the skull is looked at in front, we see beneath the forehead two conical sockets for the eyes, termed the *orbits*, and between them the bony prominence of the nose, beneath which is a large aperture medianly divided by a vertical partition and forming the front nostrils, or *anterior nares.*

Beneath the outer and lower angle of each orbit the bony projection of the cheek is noticeable, termed the malar[2] prominence; and the skull is bounded below (the mandible being removed) by the free border which gives attachment to the teeth, and is termed *alveolar*, because the teeth are lodged in

[1] From ζύγωμα, a bar.
[2] From *mala*, the cheek-bone.

special bony sockets to which the name alveoli has been applied.

When the skull is viewed in profile the sharp bony projection of the nose is seen in front and the round prominence of the occiput behind, while from the malar prominence the zygoma extends backwards to above the mastoid process—enclosing a fossa (in which is placed a muscle called the "temporal") and having beneath its hinder end a noticeable aperture which is the external bony opening of the ear. A ridge also runs upwards from the malar prominence and forms the external margin of the bony orbit.

The skull is said to be divided into certain *regions*. Thus we have the base or *basilar* region, and opposite to it the vertex, sinciput, or *sincipital* region; we have the region of the forehead or *frontal* region, and opposite to it that of the back of the head or the *occipital* region.

At the side of the head we have posteriorly and above, the *parietal*[1] region; beneath this and within the arch of the zygoma, the *temporal* region (to which is attached the temporal muscle before referred to), separated from the orbital region by the outer, hinder bony wall of the orbit.

The skull is made up of different bones of very different sizes and shapes. When it is looked at from above, a transverse zigzag line of union is seen to run across behind the forehead. This is called the *coronal* suture.[2]

Running directly backward from this, for some distance along the middle line of the vertex, is another suture, termed *sagittal*, and it ends behind by joining a wide V-shaped suture with the apex upwards, which is called *lambdoidal*.[3]

Turning now to the lower jaw, this when attached to the skull is seen to fit, by a rounded head, into a shallow cavity placed on each side in front of the external auditory opening, and termed the glenoid[4] surface.

The number of bones forming the skull decreases, with age, by anchylosis. In its mature condition the skull of man consists of the following bones, which it will be well to notice separately :—

2. The OCCIPITAL bone is of course that of the occiput, and it surrounds the great occipital foramen (or *foramen magnum*). Naturally (when the bones of the skull are separated

[1] From *paries*, a wall.

[2] Because it is somewhere near the part where a crown or garland would be placed.

[3] From its being like the Greek letter λ.

[4] From γλήνη, a socket.

at their sutures) it comes away in one piece with a very large and irregularly shaped bone, the "sphenoid," with which it is connected by a solid bony isthmus (forming the middle of the base of the skull), which isthmus has to be sawn across in order to detach the occipital bone for the purpose of anatomical study. Above the occipital foramen the occipital bone forms an expanded plate (the *squama*), marked exteriorly by transversely extended "curved lines."

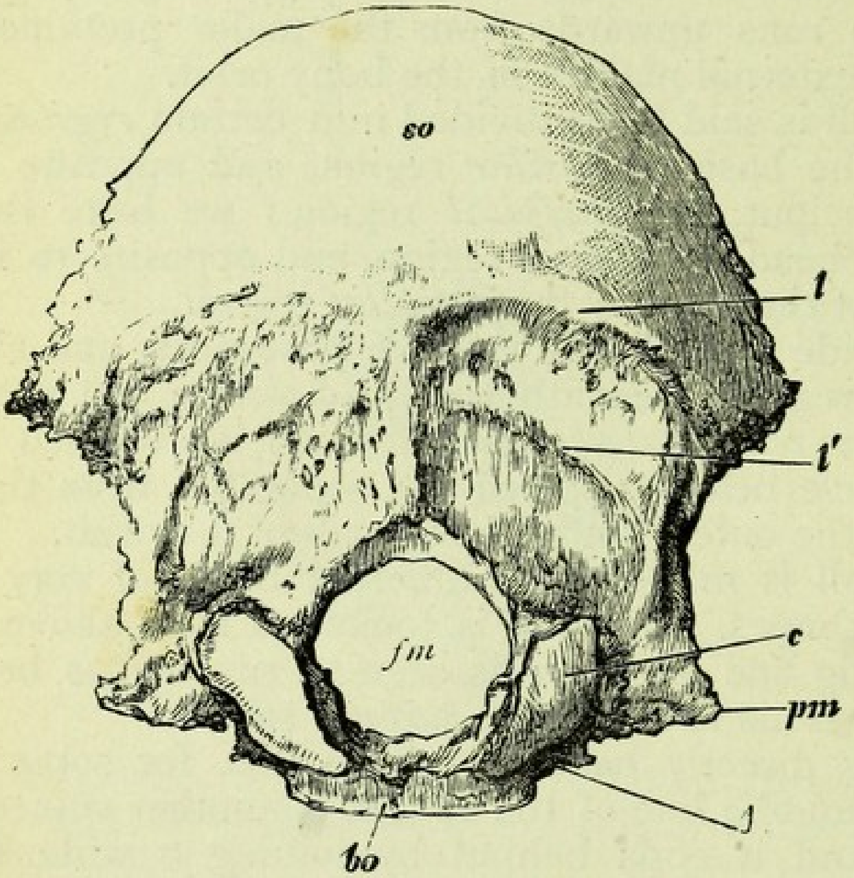

FIG. 85.—OUTER SURFACE OF MAN'S OCCIPITAL BONE.

bo, basilar part or body of the bone which unites with the body of the sphenoid; *c*, one of the two condyles; *l*, superior curved line; *l'*, inferior curved line; *pm*, one of the jugular eminences; *so*, the squama, or expanded upper part of the occipital; 1, condyloid foramen; *fm*, foramen magnum.

The "condyles," before noticed, are attached to this bone, and external to each is a slight roughened process called the "jugular" eminence, because it borders that aperture of the skull through which the jugular vein comes out. Behind each condyle is a small hole, or foramen, which allows the hypoglossal[1] nerve to pass out from the brain.

The occipital unites, as has been said, with the sphenoid in front. Above this junction it articulates on each side with the bone from which springs the mastoid process and zygoma,

[1] For this and other nerves see Lesson VIII.

and which is called the temporal bone. Above the mastoid it articulates on each side with one of the two great plate-bones which roof the skull at the top and sides, and which are called the parietals.

In a new-born child the occipital bone consists of four parts: (1), a median piece in front of the foramen magnum, and which, as contributing to form the base of the skull, is called "basilar;" (2 and 3), two "lateral" pieces, one on each side of the foramen magnum, each supporting a condyle, and pierced for the hypoglossal nerve; (4), a large median plate placed above the foramen magnum, and therefore called a "*supra-occipital*," and which shows traces of its origin from more than one centre of ossification.

3. The PARIETAL bone is very large, and is connected with its fellow of the opposite side by the sagittal suture, with the occipital behind by the lambdoidal suture, anteriorly with the frontal by the coronal suture, and below with the temporal bone by a suture which is called *squamous*, because the margins of the bones it joins are so bevelled off that the temporal lies on the parietal like a scale.

The parietal arises from but one centre of ossification.

4. The remaining bone of the skull-roof is the FRONTAL, which, single in the adult, is at birth divided into two parts by a line of separation which continues onwards the median separation between the contiguous parietals.

The anterior end of this bone is, as it were, bent sharply backwards on each side to form two plates which roof the bony orbits, while between these plates a space is left filled up naturally by the bone forming the summit of the nasal cavity, and called the ethmoid. Above the margins of each orbit are slight transverse curved prominences, called the superciliary and supra-orbital ridges, while each margin itself runs out into what is named the *external angular process*, at each outer inferior angle of the frontal bone, and joins the bone of the cheek, or malar. Besides the unions just mentioned, the frontal unites with bones to be hereafter described, namely the sphenoid, nasals, lachrymals, and maxillaries.

5. On each side of the skull we find an exceedingly complex bone called the TEMPORAL. (See Figs. 83, 89, 90, and 91.) Part of it, as already mentioned, articulates with the parietal by a squamous suture, and it is this part which forms the hinder part of the zygoma and the articular "glenoid" surface for the lower jaw.

A portion of bone which bounds the external opening of the ear below, is continued inwards as a tube having on its under surface a rough ridge. On account of its connexion with the drum of the ear it is called "*tympanic*," and forms the floor of the passage leading into the internal ear or *meatus auditorius externus.* Between it and the glenoid surface is a narrow slit or fissure, called the *fissura Glaseri* (which transmits the *chorda tympani* nerve), while behind it hangs down a long, very slender process, termed "styloid," posterior to and outside the root of which is the *stylo-mastoid foramen*, which transmits the facial nerve.

The rest of the bone consists of two parts, namely, (1) the mastoid process already referred to, and (2) an irregularly shaped piece (which on account of its hardness is called the petrous[1] bone) projecting inwards like a wedge on the base of the skull, between the occipital and the sphenoid. In addition to the connexions already noted, the temporal joins the malar by means of its zygomatic process.

The petrous and mastoid portions enclose the inner and essential parts of the ear, the internal canal of which (called *meatus auditorius internus*) opens on the inner surface of the petrous, wedgelike piece, and gives entrance to the nerve of hearing.

Towards the apex of the wedgelike projection is seen a large aperture which is one end of a canal, the other end of which opens on the under surface within and in front of the styloid process. This is the canal for the internal carotid artery, which thus takes its way right through the petrous portion of the temporal bone. Internal to its anterior opening and at the angle formed by the junction of the petrous part of the temporal bone with its squamous part, are two small openings placed one above the other. These are the apertures of two tubes (which run backwards, parallel and apposed like the barrels of a double-barrel gun, in the substance of the bone), the lower of which is the Eustachian tube, and conveys air from the mouth to the internal ear. The upper tube gives passage to the small tensor tympani muscle. A sharp ridge runs inwards and forwards from the root of the styloid process. This ridge is termed the *vaginal* process.

The temporal bone arises by very distinct and significant ossifications.

Thus we have (1) the squamous and zygomatic portions forming one element; (2) the tympanic portion, which is at first a mere delicate ring of bone; (3) the styloid process,

[1] From πέτρος, a stone.

vhich is at birth separate from a little cylindrical piece of)one which afterwards forms its root, and which is called he *tympano-hyal.*[1]

Besides these three elements, three other distinct ossifica-ions extend and coalesce to form the petrous and mastoid)ortions of the temporal bone, and are distinguished by their liverse relations to parts of the internal organ of hearing. Continuing our enumeration, we have (4) an ossification which gives rise to the upper part of the petrous portion (that which s visible on the inside of the skull) and to part of the mastoid. t forms the upper margin of what will hereafter be noticed ıs the *fenestra ovalis*[2] of the internal ear, and is especially elated to the anterior vertical semicircular canal. It is called he *pro-otic.*[3] (5) One which gives rise to the lower part of he petrous portion (that which is visible on the base of the kull) and forms the carotid canal. It also forms the lower)art of the *fenestra ovalis*, and surrounds entirely what is ermed the *fenestra rotunda.* It is called the *opisthotic.*[4] 6) One which gives rise to the mastoid process, and which s developed upon the posterior part, and what we shall here-.fter know as the posterior vertical semicircular canal of the nternal ear. It is called the *epiotic.*[5] The mastoid process s not prominent at birth.

6. The SPHENOID[6] is a very complex bone, and has been ikened to a creature with a small body, two pairs of wings, .nd two legs.

The central part, or body (which is anchylosed with the)asilar part of the occipital), has on its upper surface a leepish pit, called the *sella turcica* or *pituitary fossa*, because : receives the pituitary body of the brain. It is bounded)ehind by a vertical plate, termed "clinoid,"[7] from the ummit of which projects on each side a "clinoid process."

From each side of the body there projects upwards, out-vards, and forwards a large more or less triangular plate, alled the greater *ala*, or wing of the sphenoid, which also ends a lamellar process downwards. At the root of the ring are three holes. The innermost and smallest—the idian—transmits the vidian nerve. Above and external to

[1] Discovered and named by Professor Flower ("Osteology," p. 123). Every)ne connected with the tongue-bone, or hyoid, has the term *hyal* as a part of s name.

[2] It has also been noticed in the Eighth Lesson of "Elementary Physiology."

[3] Πρό, before, and οὖς, ὠτός, the ear.

[4] Ὄπισθε, behind.

[5] Ἐπί, above.

[6] So called from σφήν, a wedge, and εἶδος, like.

[7] From κλίνη, a bed.

this is the *foramen rotundum*, through which passes the second branch of the fifth nerve. Behind this is a larger foramen (termed from its shape *foramen ovale*), which gives exit to the third branch of the fifth nerve. On each side of the sella turcica, at its hinder part, is a groove for the carotid artery. This groove is bounded in front and externally by a small tapering piece of bone which is called the *lingula sphenoidalis*, and which is situated between the body of the bone and the greater ala.

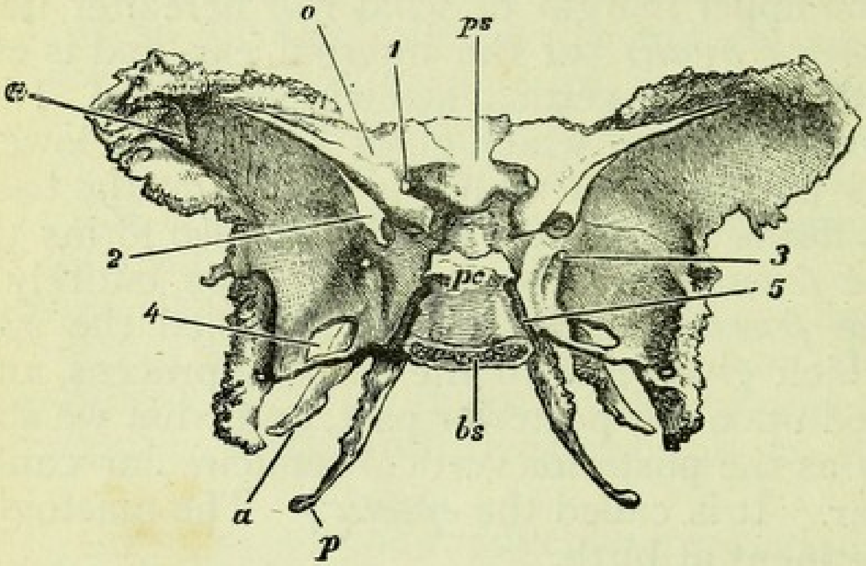

FIG. 86.—MAN'S SPHENOID BONE SEEN FROM ABOVE.

a, its greater wing—the lower letter *a* points to that downward continuation of the great wing which is called the external pterygoid process; *bs*, its body—showing a cut surface behind, where it has been separated from the occipital bone; *pc*, the clinoid plate, bounding the pituitary fossæ behind; *ps*, the anterior, or pre-sphenoidal part of the body of the bone; *o*, lesser or orbital wing; *p*, internal pterygoid process; 1, optic foramen; 2, sphenoidal fissure; 3, foramen rotundum; 4, foramen ovale; 5, groove for the carotid artery.

The greater ala passes up between the squamosal and the frontal to the parietal bone, and forms the anterior part of the temporal fossa and the hinder, outer part of the bony orbit.

The downwardly extending plate is called the external pterygoid[1] process. The internal pterygoid process is more slender, terminating below in a hooked-like, or hamular, process. The two internal pterygoid processes form what have been fancifully called the legs of the sphenoid. Between the internal and external pterygoid process of each side is a space called the pterygoid fossa, which is closed behind by a palate bone.

From the anterior part of the body the much smaller wings called "orbital" project outwards, one on each side. The

[1] From πτέρυξ, a wing

base of each is perforated by the foramen, which transmits the *optic* nerve; behind the foramen projects backwards a small "*anterior clinoid process.*"

Each orbital wing forms the hindermost and innermost part of the roof of the orbit.

The greater ala and the orbital wing of each side are separated by a long but narrow space, termed the *sphenoidal fissure.* This transmits the third, fourth, and sixth nerves and the first branch of the fifth nerve. In addition to the junctions already noted, each ala unites with the malar bone of its own side, and the body of the sphenoid is in contact with a bone, the vomer, hereafter to be noticed.

At an early period the sphenoid bone may be said to be made up of ten parts: (1) the bulk of the body; (2) the anterior part of the body, or pre-sphenoidal part; (3 and 4) a pair of great wings and external pterygoid processes, or two alisphenoidal parts; (5 and 6) a pair of lesser wings, or orbito-sphenoidal parts; (7 and 8) the pair of internal pterygoid processes, or proper pterygoid bones; and (9 and 10) the lingulæ sphenoidales.

7. The ETHMOID,[1] or sieve-like bone, is of singular delicacy of structure and complexity of shape. It is placed between the skull proper and the face, hanging down between the orbits. It consists of a transverse *cribriform plate* and of three vertical portions. The cribriform plate is so called from its sievelike condition (being perforated with numerous small holes for the nerves of smell); it extends between the orbital plates of the frontal and the three vertical portions. The first of these three is median, and its summit, called *crista galli*, projects a little upwards into the cranial cavity, while the main part is below the cribriform plate, and forms the upper and front part of the partition between the nares, whence it is termed the "*median ethmoid.*"

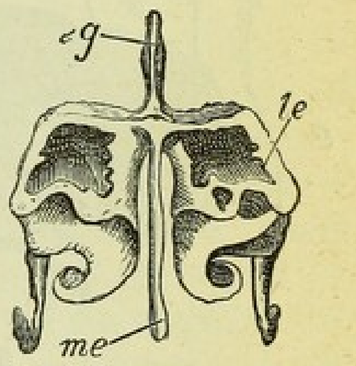

FIG. 87.—MAN'S ETHMOID BONE.

eg, Crista galli, rising vertically above the horizontal surface of the cribriform plate; *le*, lateral mass of the ethmoid; *me*, median ethmoid.

The two other parts hang down from the under surface of the cribriform plate, and each is termed a "*lateral ethmoid.*" The outer surface of each of these is smooth, and appears

[1] From ἠθμός, a sieve.

in the inner wall of the orbit as what is called the *os planum*, which is bounded above by the frontal, behind by the sphenoid, in front by the lachrymal, and below by the maxilla. The inner surface is swollen and irregular. That part of it immediately below the cribriform plate is called the upper spongy bone, or superior turbinate, or turbinal,[1] the part below being termed the middle turbinate.

Besides the junctions already noted, the ethmoid unites with the sphenoid behind, and with the nasals, vomer, lachrymals, palatines, and lower turbinate bones (or turbinals).

8. The MAXILLARY bone supports on each side the teeth of the upper jaw, and forms the bulk of that jaw, and contributes to form the cheek, the orbit, the nasal passage, and the palate. The two maxillary bones meet in the middle line below the anterior nares, where each projects as a sharp process—the *anterior nasal spine*. Each sends up a prolongation (the *nasal process*) to the frontal, bounding the inner side of the orbit anteriorly, and having at its hinder side a lachrymal bone, and on its anterior side a nasal bone. Its hinder surface exhibits a vertical groove. On the opposite or external side the maxillary bone sends a process outwards, which joins the malar, and is called the *malar process*. Above, the bone exhibits a smooth horizontal surface (the orbital plate), which forms the floor of the orbit. In front the bone has a concavity, termed the *canine fossa*, between which and the lower margin of the orbit is a foramen (called *infra-orbital*) which transmits the second branch of the fifth nerve.

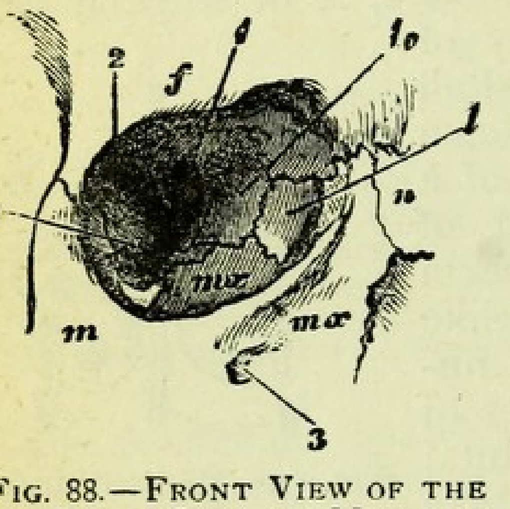

FIG. 88.—FRONT VIEW OF THE RIGHT ORBIT OF MAN.

a, greater wing of the sphenoid; *f*, frontal bone; *l*, lachrymal; *le*, os planum; *m*, malar; *mx*, maxillary; *n*, nasal; 1, optic foramen; 2, sphenoidal fissure; 3, infra-orbital foramen.

From within the alveolar border each maxilla sends inwards a *palatine* plate, which is joined by the palate bone posteriorly, but which internally meets its fellow of the opposite side, except where the opening of the *anterior palatine canal* separates them.

In the body of the bone is a large cavity called the Cave of Highmore, or the *Antrum Highmori*.

[1] So called from being curved like a turbinated shell.

Besides the articulations mentioned, the maxilla joins with the ethmoid, the vomer, and the inferior turbinal.

At birth there may be a suture on the palatine surface of the bone, separating off that small front part in which the incisor teeth are afterwards implanted.

9. The MALAR bone is irregularly triangular in shape. It forms the outer wall of the bony orbit, and connects the zygomatic process of the squamous part of the temporal bone with the maxilla. It joins above with the external angular process of the frontal, and posteriorly with the great ala of the sphenoid.

The NASALS are small bones placed side by side above the nares, joining the frontal above, and separating the nasal processes of the two maxillary bones one from the other.

The LACHRYMALS are small bones, one of which is placed at the anterior part of the inner wall of each orbit, having the frontal above, the os planum of the ethmoid behind, the nasal process of the maxilla in front, and the orbital plate of the same bone below. Each is marked with a vertical groove, which, by joining the similarly directed groove (before spoken of) on the posterior side of the maxillary nasal process, forms a canal leading from the orbit to the nasal cavity, and termed lachrymal because the tears pass down it.

10. The palate bones, or PALATINES, are very irregular in shape, and wedged in between the maxilla and the pterygoid processes of the sphenoid. Each consists of a long vertical plate, from the bottom of which a smaller horizontal plate projects inwards, meeting its fellow of the opposite side in the middle line, and completing the palate behind the maxilla. The palatine contributes to separate the nasal fossa from the mouth, and extends up into the orbit, where it appears at the back part of its inner wall beneath the os planum, separating the sphenoid from the maxilla, and helping to bound the *spheno-palatine foramen*. Its outer side is grooved vertically, the groove forming, with the help of the maxilla, the *posterior palatine canal*. Its posterior surface is interposed between the external and internal pterygoid processes of either side, thus completing the pterygoid fossa in front. The palatine articulates also with the vomer and inferior turbinal.

11. The VOMER[1] is a single median bone extending down from the sphenoid and median ethmoid to the upper surface of the bony palate, thus completing the median partition between the nostrils. Its hinder margin marks the partition

[1] *I.e.* ploughshare, so called from its shape.

spoken of already as medianly dividing the posterior nasal openings. In the infant this bone consists of two lateral portions.

The inferior turbinate bones, or *lowest* TURBINALS, extend (one on each side) from before backwards along the nasal fossæ, attached, though but slightly, to the inner side of the maxillary and palatine bones.

12. The only naturally separated bone of the skull in the adult, namely the lower jawbone, or MANDIBLE, consists of a curved osseous band, almost of the same depth throughout, and convex forwards. It has a smooth rounded inferior edge, but its upper edge is festooned by unequal cavities, forming sockets for the teeth, whence this upper border is termed "alveolar." The whole band is termed the body of the mandible; a vertical line at its middle in front is called the *symphysis*,[1] and each half of the body external to this line is called the *horizontal ramus* (or branch). At its hinder end each horizontal ramus turns suddenly upwards at a slightly obtuse angle, and terminates above in two processes, the front one of which is pointed and is called the "*coronoid process*," while the hinder one ends in a rounded head, "the *condyle*," mounted on a narrower part termed the "*neck*."

This nearly vertical part on each side is called the *ascending ramus*, and the point where its posterior margin meets the inferior margin of the horizontal ramus is named the "*angle*." (Fig. 83.)

The condyle is wider than it is long, and fits into the glenoid cavity of the squamous part of the temporal bone. An inter-articular fibro-cartilage (with one synovial sac above it and one below it) is interposed between the two bones, and the ascending ramus is also attached to the skull by strong ligaments.

The coronoid process rises nearly as high as the condyle, and has inserted into it the temporal muscle which adheres, at its origin, to the side of the skull within the arch of the zygoma.

On the inner side of the ascending ramus is a foramen, called the *inferior dental*, and another, the *mental foramen*, is placed, more forwards, on the outer side of the horizontal ramus.

The symphysis is concave vertically in front, the lower border of the mandible projecting at the symphysis to form the chin.

[1] From σύμφυμι, to grow together.

At birth the bone consists of two parts, which are separated at the symphysis, and at first the ascending ramus slants much backwards, but gradually rises till it is nearly vertical in the adult.

13. Another bone, often not reckoned as part of the skull, is the os hyoides (so named from its resemblance to the Greek letter *υ*), which is placed beneath the root of the tongue.[1] It consists of a "body" with a pair of processes on each side, one large (the great cornu) and one small (the lesser cornu, or corniculum). The *body* is transversely oblong, hollowed behind, convex in front, and narrow from before backwards. It is called the *basi-hyal.*

The great *cornua* extend backwards from the lower outer angle of this "body;" they are rather long and nearly straight, and though at first distinct bones, become anchylosed to the basi-hyal. Each is also termed a *thyro-hyal.*[2]

The lesser cornua, or *cornicula*, arise from the upper aspect of the "body" at its junction with the greater cornua, and each corniculum (or, as it is also called, *cerato-hyal*)[3] is attached to this "body" by a synovial sac, though sometimes by bony union. Each corniculum is short and conical, and united by a ligament to the styloid process of the temporal bone.

14. Considering now the OUTSIDE OF THE SKULL as a whole, we find on its base in front the alveolar margin,—forming a graceful curve, and surrounding the bony palate (with its palatine foramina), which extends a little further back than the teeth, and ends in the posterior free margin of the palatine bones.

Behind the palate are the posterior nares, on each outer side of which is a pterygoid fossa, bounded as before described. In the middle of the *basis cranii* is the basilar part of the occipital bone, behind it the foramen magnum, condyles, and condyloid foramina.

On each side is the petrous part of the temporal bone, with its styloid and vaginal processes and its carotid and stylomastoid foramina.

Between the front end of the petrous bone and the basioccipital is, in the dry skull, an opening called the *foramen lacerum anterius.*

Between the hinder part of the petrous bone and the lateral

[1] For its more precise relations see Lesson XII. : the Larynx.
[2] From its being placed close to the thyroid cartilage of the larynx.
[3] Κεραϛ, a horn.

part of the occipital, is an opening named the *foramen lacerum posterius*, which transmits, besides the jugular vein,

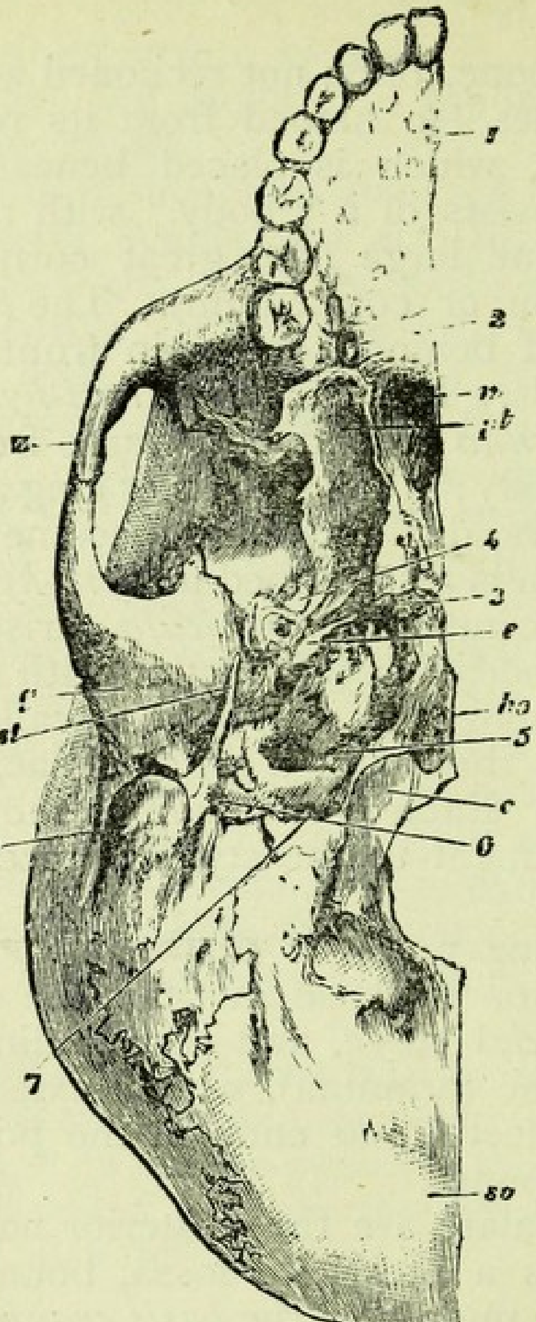

FIG. 89.—OUTER VIEW OR UNDER SURFACE OF THE RIGHT SIDE OF MAN'S SKULL.

bo, body of the occipital bone; *c*, occipital condyle; *e*, anterior end of Eustachian tube (between *e*, 5, and the vacuity behind 3, is the petrous part of the temporal bone—somewhat triangular in shape, with its apex forwards); *g*, glenoid surface of the temporal bone; *m*, mastoid process; *n*, posterior nares; *pt*, pterygoid fossa; *so*, squama of the occipital bone; *st*, styloid process; *z*, zygomatic malar bone, joining zygomatic process of temporal bone; 1, anterior palatine foramen; 2, posterior palatine foramen; 3, points in front of the foramen lacerum anterius; 4, foramen ovale; 5, carotid canal; 6, stylo-mastoid foramen; 7, foramen lacerum posterius.

the glosso-pharyngeal, par vagum, and spinal accessory nerves.

Between the outer side of the petrous bone and the adjacent margin of the ala of the sphenoid is a groove for the reception of the Eustachian tube.

Behind the foramen magnum is the great occipital expanse.

On each side of the base of the skull we find the zygoma (arching but little outwards), the glenoid surface, the external auditory meatus, and the mastoid process.

Looking at the side of the skull, we see a fissure not yet noticed. This is the *pterygo-maxillary*, which runs up between the posterior border of the maxilla and the adjacent pterygoid process. At its summit it meets the inner end of another fissure, namely the *spheno-maxillary*, which runs forwards and outwards between the inferior margin of the great ala of the sphenoid and the upper part of the maxilla.

These two fissures by their junction form an angular depression called the *spheno-maxillary fossa*, and into it open the foramen rotundum, the vidian and spheno-palatine foramina, and the upper end of the posterior palatine canal.

15. In the INSIDE OF THE SKULL, as seen from above when a horizontal section is made and its top removed, we note the following structures. In the middle, in front, the crista galli and cribriform plate, bounded on each side by the orbital plates of the frontal (which are but slightly convex), and behind by the anterior part of the sphenoid and orbital wings, each pierced at its base by the optic foramen, and having a sharp posterior margin marking off the hinder limit of what is called the *anterior fossa* of the skull.

The *middle fossa* includes, in its centre, the basilar part of the sphenoid (with the pituitary fossa and posterior clinoid process), and on each side, the great ala of the sphenoid (pierced towards its root by the round and oval foramina, and leaving the sphenoidal fissure between it and the orbital wing), the squamous part of the temporal bone, and the anterior part of its petrous portion—at the inner end of which is seen the anterior end of the carotid canal opening immediately above the foramen lacerum medius.

A ridge running forwards and inwards along the petrous bone defines its anterior part from its posterior, and at the same time the anterior margin of the *posterior fossa* of the skull. This ridge has attached to it a membrane called the *tentorium*, which divides the cerebellum from the cerebral part of the brain. The *posterior fossa* includes the hinder part of the petrous bone with its internal auditory meatus, the foramen lacerum posterius and condyloid foramen, and, in the middle, the foramen magnum and basi-occipital.

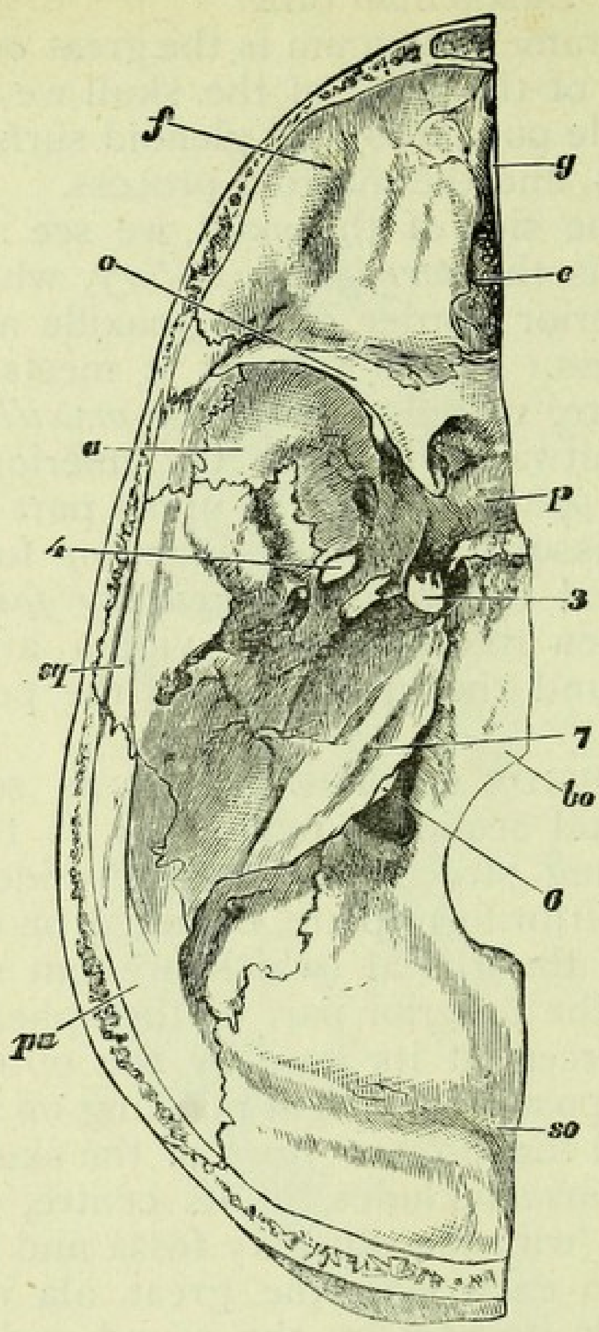

FIG. 90.—A VIEW OF THE UPPER, OR CEREBRAL, SURFACE OF LEFT SIDE OF MAN'S SKULL.

a, greater wing of the sphenoid; *bo*, base of the occipital; *c*, cribriform plate; *f*, orbital plate of frontal; *g*, crista galli; *o*, lesser or orbital wing of the sphenoid; *p*, pituitary fossa; *pa*, parietal; *so*, squama of occipital; *sq*, squamous part of temporal bone; 3, foramen lacerum anterius; 4, foramen ovale; 6, foramen lacerum posterius; 7, meatus auditorius internus—in the petrous part of the temporal bone.

The removed cap of the skull is smooth within, showing sundry slight depressions, and amongst them a longitudinal median groove, to which is attached the membrane called the *falx*, which extends back from the crista galli and dips in between the two upper halves of the brain.

When the skull is divided vertically and in the direction of the sagittal suture, we may note the vast size of the brain cavity in proportion to the face; also the horizontal condition of the cribriform plate and foramen magnum, and the advanced position of the latter approaching the middle line from behind forwards.

The basilar parts of the occipital and sphenoid bones are seen to become rapidly thicker as we go forwards; they form

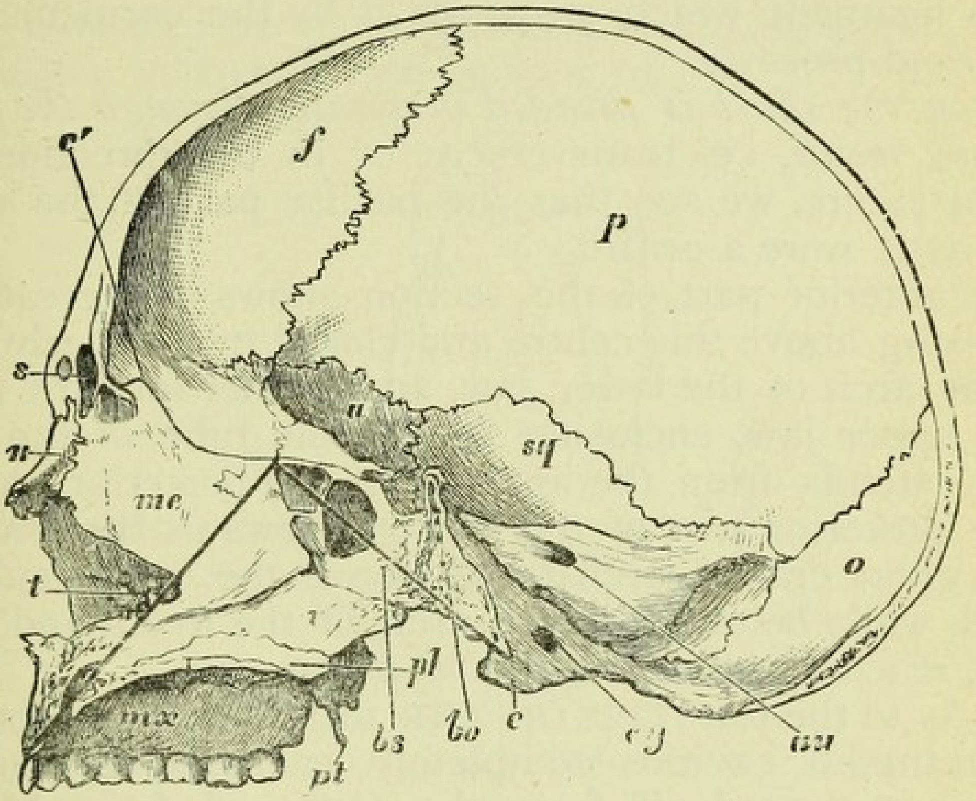

FIG. 91.—VERTICAL, LONGITUDINAL SECTION OF MAN'S SKULL.

a, greater wing of the sphenoid; *au*, meatus auditorius internus; *bo*, body of the occipital bone; *bs*, body of the sphenoid; *c*, condyle; *c′*, crista galli; *cy*, condyloid foramen; *f*, frontal; *me*, median ethmoid; *mx*, palatine plate of the maxillary; *n*, nasal; *o*, squama of the occipital bone; *p*, parietal; *pl*, palatine bone; *pt*, internal pterygoid process; *s*, frontal sinus; *sq*, squamous part of temporal bone (beneath it is the petrous part of that bone, with the opening *au*); *t*, lowest turbinal bone; *v*, vomer. The straight line passing upwards and forwards from the hinder end of the body of the occipital bone, represents the *basi-cranial axis*. The line passing downwards to the front of the jaw, represents the *basi-facial axis*.

the true axis of the skull, and a line drawn from the anterior margin of the foramen magnum to the front end of the middle part of the upper (or cerebral) surface of the sphenoid is called the *basi-cranial axis*. A line drawn from the same point of the sphenoid plate to the front part of the alveolar margin of the maxilla is the *basi-facial axis*, and the two axes in man form an angle which varies from 90° to 120°.

The basi-cranial axis forms with the foramen magnum a very obtuse angle, while with the cribriform plate it forms an obtuse one, open downwards and forwards.

The extreme length of the cranial cavity is always more than $2\frac{1}{4}$ times that of the basi-cranial axis, while it may be nearly $2\frac{3}{4}$ times the length of the latter.

The half of the lower jaw forms an arc joining the skull above directly at the glenoid surface.

The half of the hyoid bone forms a much smaller arc behind the former, and joined to the skull indirectly, namely by the ligament which suspends it by the corniculum from the styloid process.

When the skull is divided vertically through the external auditory meati, i.e. transversely, or in the direction of the coronal suture, we see that the basilar part of the occipital forms as it were a centre.

The anterior part of the section shows the great cranial arch rising above this centre and closed in front, while below it is the arch of the lower jaw, and further forward the arch of the upper jaw, enclosing the double tube of the nostrils which extends from the anterior to the posterior nares.

The posterior part of the section shows us the hinder part of the great cranial arch rising above the centre and closed behind, while below it is the arch of the hyoid and its ligaments, reaching up to the styloid processes.

16. As to the CAVITIES OF THE SKULL: the orbits in man are pyramidal cavities completely encircled by bone, and each so separated off from the temporal fossa behind it, by the malar and alisphenoid, that the elongated spheno-maxillary fissure is the only opening left.

At the back are the optic and round foramina, and between them the sphenoidal fissure, the vidian foramen being hidden from view.

Within the anterior margin on the inner wall of each orbit is the lachrymal foramen.

The two orbits are separated from each other in part by the cranial cavity (above the cribriform plate), and in part by the nasal cavity (below the cribriform plate).

The *nasal fossæ*, extending backwards above the palate from the anterior to the posterior nares, and enclosed between the maxillæ, are separated from each other by the median, ethmoid, and vomer, and in front of these by cartilage. The three turbinals project inwards from the outer wall of each fossa, and beneath the lowest the inferior termination of the lachrymal canal opens.

In the substance of the frontal bone, just above the nasals, are, almost always, certain cavities filled with air, called the *frontal sinuses.* These communicate with the nasal fossæ below, through the middle turbinals.

The body of the sphenoid and the maxillæ also contain large air-holding cavities, termed the *sphenoidal* and *maxillary sinuses*, and opening respectively beneath the upper and middle turbinals into the nasal fossæ.

17. In DEVELOPMENT the first appearance of the future skull is indicated by the expansion of the anterior end of the primitive groove before spoken of.

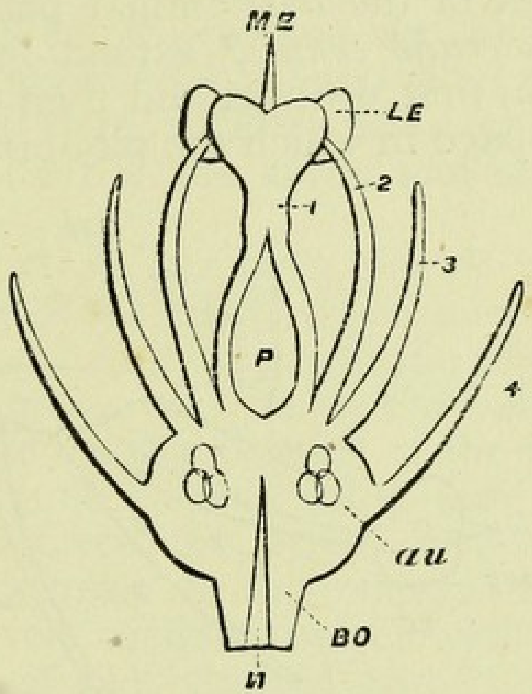

FIG. 92.—DIAGRAM OF THE FORMATION OF THE SKULL, SEEN FROM ABOVE.

BO, the plate of cartilage representing the future body of the occipital bone ; N, the anterior termination of the notochord ; *au*, the cartilaginous auditory capsule containing the internal ear ; P, the space afterwards becoming the pituitary fossa, and now enclosed on its two sides by two cartilaginous rods—the *trabeculæ cranii*, which meet in front of it at (1) to form the ethmo-vomerine plate from which the median (ME) and lateral (LE) ethmoids arise ; 2, the second cartilaginous rod, or arch, forming the maxillary arch ; 3, the third arch, forming the mandibular arch (or lower jaw) ; 4, the fourth arch, forming the hyoidean arch.

This expansion becomes subdivided by two lateral contractions (one in front of the other, on each side), so that three rounded cavities are produced, one behind, one above, and one in front of the anterior termination of the notochord—the primitive skull being sharply bent down just in front of the anterior termination of the notochord.

In the walls of these rounded expansions, or vesicles, no quadrate thickenings occur similar to those which are developed (one in front of the other) on each side of the chorda dorsalis, and which are the precursors of the vertebræ.

A solid, flattened mass surrounds the anterior termination of the chorda dorsalis, and forms the cartilaginous foundation and precursor of the basilar part of the occipital bone, and may be called the basi-cranial plate.

Continuous with this on each side is a rounded mass of cartilage which is the precursor of the petrous parts of the temporal bone and of the lateral parts of the exoccipital; and the latter cartilages, growing up to meet together above, enclose the foramen magnum with a cartilaginous ring.

From the front of the basi-cranial plate two cartilaginous rods, called *trabeculæ cranii*,[1] extend forwards and downwards. These at first diverge, and then converge and meet, thus leaving a space in which the pituitary fossa comes to be placed.

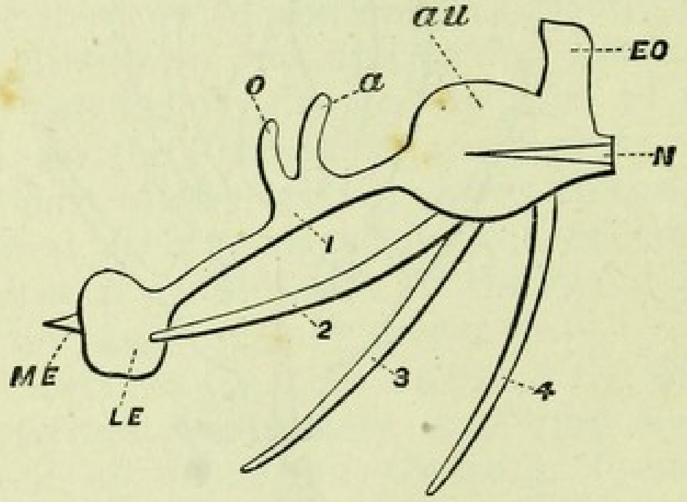

FIG. 93.—DIAGRAM OF THE FORMATION OF THE SKULL, SEEN LATERALLY.

N, the anterior termination of the notochord in the cartilaginous occipital mass; EO, a lateral upward extension of that mass, forming the foundation of the future lateral part of the occipital bone; *au*, the auditory capsule; *a* and *o*, the cartilaginous beginnings of the future "greater" and "orbital" wings of the sphenoid; 1, one of the trabeculæ cranii running forwards to expand in the ethmo-vomerine plate or foundation of the future median (ME) and lateral (LE) ethmoids; 2, the second (maxillary) arch running forwards to abut against the ethmo-vomerine cartilage; 3, the mandibular arch; 4, the hyoidean arch.

This prolongation forwards, after sending up on each side two cartilaginous representatives of the sphenoidal wings, forms, as has been indicated, a median plate (termed Ethmo-vomerine), which sends downwards three other plates to form the median and lateral ethmoids.

The rest of the walls and roof of the skull are completed by membrane only.

Besides the trabeculæ, other cartilaginous rods extend

[1] From *trabecula*, the diminutive of *trabes*, a beam or rafter.

downwards from the basi-cranial plate, or rather from the lateral cartilage contiguous with it.

Thus a second rod, external to the trabecula, on each side, passes forwards (almost parallel with the trabecula adjacent to it) and fuses with the Ethmo-vomerine plate.

A third rod descends and fuses with its fellow of the opposite side, so forming the groundwork of the lower jaw, which is thus laid in what is often called the first visceral arch, but which is really the *third*.

The next, or fourth cartilaginous rod, meets with its fellow below only by means of the interposition of soft structures, and lays the foundation of the styloid processes and cornicula of the os hyoides, which thus are contained in what is really the *fourth visceral arch*, though often called the second.

The *fifth visceral arch* develops on each side, at its ventral part, the precursor of the cornu and body of the hyoid bone.

Ossification occurs, as has been stated, in more than one point of most of the bones which are reckoned as single bones in the adult man. Thus it occurs in the lateral and superior parts of the occipital as well as in the basilar part ; in the wings and inner pterygoid processes of the sphenoid, as well as in those two parts of its body which may be distinguished as the basi-sphenoid and the *pre-sphenoid*—the latter supporting the orbital wings. In the temporal bone, as has been pointed out, many very distinct ossifications occur.

The ossification of the ethmoid and of all the turbinals and vomer takes place in, around, and from the ethmo-vomerine plate and the cartilages of the trabeculæ, or first visceral arches.

The palatine bones, internal pterygoid processes, and maxillary bones, are ossifications connected with the second visceral arches.

The mandible—which arises from one point of ossification on each side—invests the ventral end of the cartilage (called Meckel's) of the third visceral arch.

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18. Turning now to OTHER VERTEBRATES, we find that in the possession of a cranium man agrees with all except the Lancelet. This animal can hardly be said to have a brain at all, so slight is the enlargement of the anterior end of its spinal marrow : consequently its brain-case is, as might be expected, similarly imperfect, and consists merely of the

membranous investment of this terminal part of the spinal marrow.

In other Vertebrates a definite and distinct brain, enclosed in a definite and distinct brain-case of solid tissue (cartilaginous or osseous), with jaws and hyoidean appendages, is almost a constant character.

In that the skull is sharply and distinctly differentiated off from the spinal skeleton, man agrees with the vast majority of Vertebrates, and with all Vertebrates without exception above Fishes. It is possible, however, for the cartilaginous representatives of vertebræ to coalesce into one mass with the cartilaginous skull (as in the Sturgeon), or even when the skeleton is osseous (as in the Siluroid fish *Bagrus*, where these bones are suturally united). Indeed, in such cases, the transition from spine to cranium is so gradual that it is easy to mistake part of the vertebral column for part of the skull.

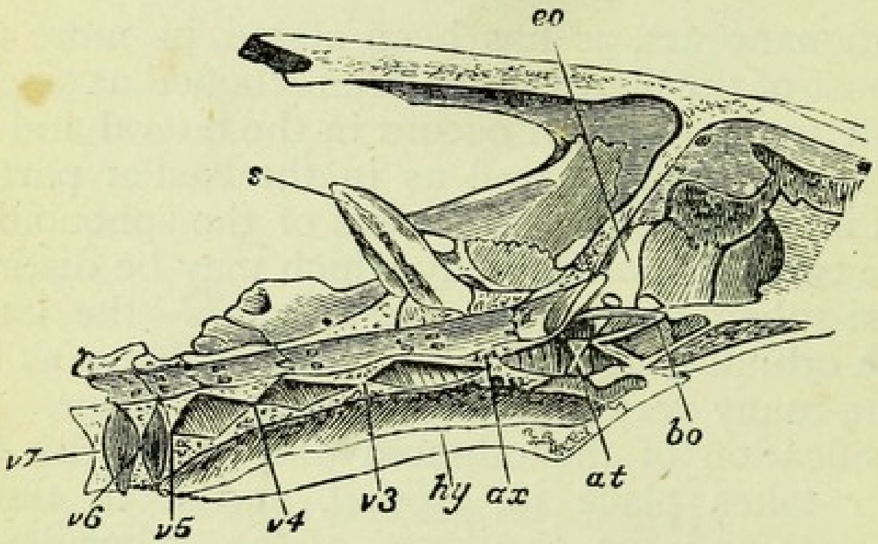

FIG. 94.—VERTICAL, LONGITUDINAL SECTION OF THE POST-AXIAL PART OF THE SKULL, AND OF THE MORE PRE AXIAL VERTEBRÆ OF THE SILUROID FISH *Bagrus*. (*After Owen.*)

at, body of first vertebra; *ax*, body of second vertebra; v^3—v^7, bodies of the next five vertebræ, each line going to the middle of a biconcave centrum; *bo*, basilar part of the occipital bone; *eo*, exoccipital; *s*, spinous process of the second vertebra. Directly above *s* is the post-axially projecting supra-occipital. *Hy*, the hypapophysial canal running beneath the first five vertebræ.

The almost completely osseous condition of the skull of man is one common to him and to his class. In the Sauropsida the skull is often eked out, as it were, by considerable tracts of cartilage or membrane, and in the Ichthyopsida the cartilaginous portion is always more considerable, and may constitute the greater part or the actual whole of the solid brain-case and annexed structures.

The shape of the skull will be spoken of afterwards, but here it may be stated that the division of it adopted in human anatomy, into cranium and face, is one which is natural. By the former we shall understand the brain-case proper, and no more. By the face we shall understand not only the bones usually included in that category in anthropotomy, but the ethmoid and parts of the sphenoid also, namely the internal pterygoid processes, which, as we have seen, arise in man about the second visceral arch.

The number of bones of which the skull is composed in man when adult is much less than in many animals ; on the other hand, it is more than in many, where, as in the class of Birds, the process of anchylosis is more rapid and extensive.

Certain small bones of the ear, called auditory ossicles, are, in works on human anatomy, included in the description of the internal ear. For this reason the full notice of these ossicles will here also be similarly deferred ; though from the important part they are said to play in many lower, and all the lowest forms, and their relations to hyoidean structures, they must be somewhat noticed even in describing the true skeleton considered as the framework of the body.

19. The OCCIPITAL bone of man represents some of the most constant ossifications of the solid cranium. The condition of union its parts present in him is the one normal in his class, though the union of its elements is often longer delayed in some Mammals than in him.

On the other hand, the occipital bone (or parts of it) may anchylose with more than it anchyloses with in man, as is the case in the Sauropsida, where, except in the Chelonians, two portions of the petrous bone (the epiotic and opisthotic) become intimately united with parts of the occipital.

In the lower forms (or Ichthyopsida), where the skull is ossified, either the main parts of the human occipital are represented by distinct bones, or only a portion of them are so represented.

The basilar process (*basi-occipital*) is a constant ossification in all except Batrachians and some Fishes, and when present in the latter (as the Cod, Perch, Pike, &c.), remains a distinct bone throughout life. It may, however, as in Batrachians and in the Lepidosiren, be represented merely by cartilage ; and this in spite of other portions of the occipital being ossified. The basi-occipital may give origin to a median descending process like a hypapophysis, and may indeed (as in the Carp) send one down so far as to penetrate the wall of the alimentary canal and serve in mastication.

The hinder end of the basi-occipital has a more important function in the Sauropsida than in man's class, as it develops a convex projecting head or condyle, which articulates with the vertebral column. In most Fishes it is concave, its concavity being applied to the concavity of the body of the first vertebra in the same way that all the bi-concave vertebræ are united together.

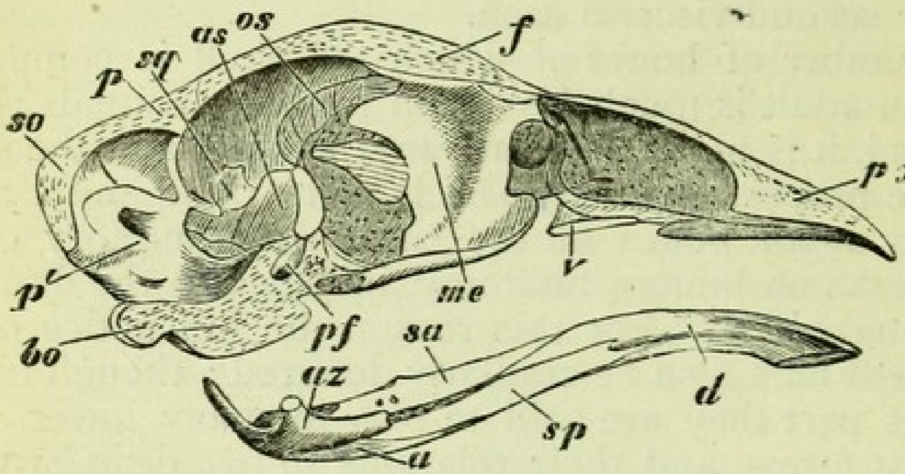

FIG. 95.—VERTICAL, LONGITUDINAL SECTION OF THE SKULL OF A FOWL. (*After Parker.*)

a, angular bone of mandible; *as*, alisphenoid; *az*, articular bone of mandible: *bo*, basi-occipital; *d*, dentary bone of mandible; *f*, frontal; *me*, median ethmoid; *os*, orbito-sphenoid; *p*, parietal; *p'*, pro-otic; *pf*, pituitary fossa; *px*, pre-maxilla; *sa*, surangular bone of the mandible; *so*, supra-occipital; *sp*, splenial bone of the mandible; *sq*, squamous part of the temporal bone, or squamosal; *v*, vomer.

The lateral parts (*exoccipitals*) are constantly ossified wherever the skull is ossified at all; and their position with regard to the spinal marrow is constant. They always transmit, either as in man by a notch, or by a foramen, the eighth pair of nerves, and also the hypoglossal nerve where it exists, but this latter is wanting in Fishes.

In the fact that the occipital condyles are mainly formed by the lateral parts (exoccipitals), man agrees with his own class. They may, however, be entirely formed by the exoccipitals, as in Batrachians; or these bones may more or less help to form one single median convex articular condyle, as in the Sauropsida.

The peculiarities as to the position of the foramen magnum will be spoken of in considering the skull as a whole.

The Squama of man, or *supra-occipital*, is of a relative size greatly in excess of that which exists in most forms, but still it may attain a yet greater importance than in him. This is the case, for example, in the Cetacea and in the Elephant, where its relative as well as absolute size is enormous.

Again, it may be divided into two parts, its upper portion being reckoned as a distinct bone (*interparietal*) as, *e.g.*, very often in Rodents. A still more divided condition of the supra-occipital may obtain, as in the Ganoid fish *Lepidosteus*.

On the other hand, as in the Frogs and Toads, the supra-occipital may be absent altogether, the lateral portions, or exoccipitals, meeting as well above as below the foramen magnum.

The faintly marked superior curved lines of the human occiput are but feeble representations of the great bony projections which the occipital bone may develop. Thus, even in one of the forms nearest to man—the Gorilla—there may be an enormous lambdoidal ridge. In Ruminants, again, this ridge may be largely developed, and have bony extensions (the horns) reaching out from it, as in the Ox.

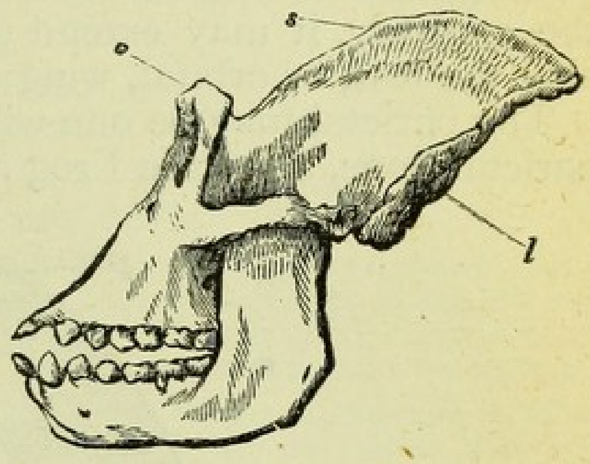

FIG. 96.—SIDE VIEW OF THE SKULL OF AN ADULT MALE GORILLA.

o, supra-orbital ridge; *s*, sagittal ridge (a lofty plate as indicated by the shading); *l*, lambdoidal ridge—the last is foreshortened as it projects laterally.

The jugular process of man may be developed to a much greater extent, bearing the name of par-occipital or para-mastoid process, as *e.g.* in the Babirussa and Capybara. It may help to form the tympanic cavity, as in Birds, or be completely absent, as in the Ichthyopsida.

A singular relationship seems often to exist between an aquatic habit and defective development of the basilar part of the occipital bone. Thus this part is altogether absent in Batrachians, it is often imperfectly ossified in Seals, and seems to be rudimentary in some of the Cetacea.

In the last-named animals, as also in very many Fishes, the supra-occipital is brought into direct connexion with the frontal—a condition very different from that of man.

20. Whereas the occipital bone of man is the representative of four distinct bones in lower animals, his PARIETAL bone, on the contrary, is in its normal condition, as it arises always from a single ossification. Indeed, not only is it never more complex than in him, but in many animals (*e.g.* the Monotremes, Serpents, and the Salmon) the two parietals anchylose at a very early period into a single, median bone.

Generally, as in man, the two parietals meet, but, as has been said in treating of the occipital, they may be encroached upon, and depressed to the side of the skull (as in the Cetacea), by the union of the last-named bone with the frontal.

The great size of the parietals of man is very exceptional, and has direct relation to the immense development of his brain. On the other hand, they may be in great part mere bars, as in many Lizards.

The parietal may give off a lamellar expansion helping to roof over the temporal fossa—as in the Turtle and the curious African Rodent *Lophiomys*.

The exclusion of the parietal from any junction with the sphenoid by that of the frontal bone with the temporal, which occasionally occurs in man, is very common in Apes. On the contrary, it may extend to join not only the greater but also the less, or orbital, wing of the sphenoid.

The parietal may be one with the frontal, forming a fronto-parietal bone, as in the Frog and Lepidosiren.

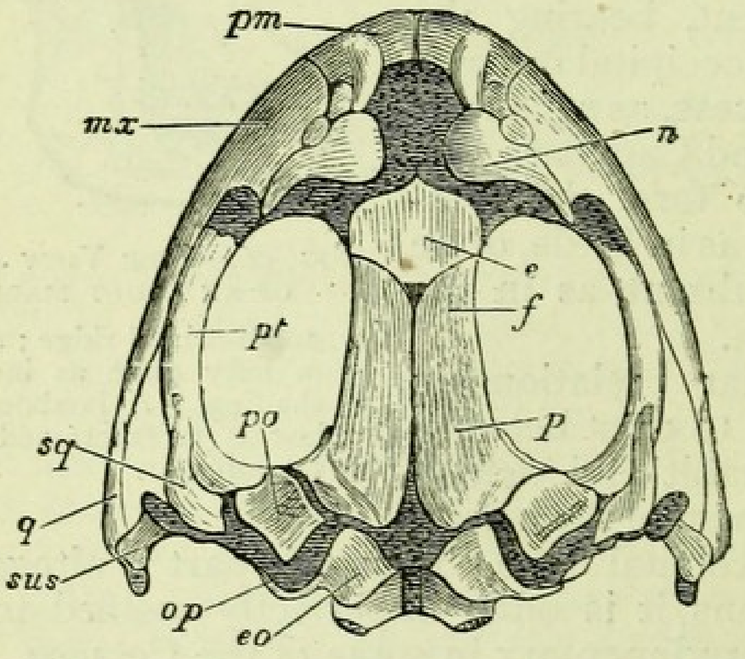

FIG. 97.—UPPER SURFACE OF THE SKULL OF A FROG. (*After Parker.*)

e, os en ceinture, or girdle-bone; *eo*, exoccipital; *f*, frontal part of fronto-parietal 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.

From within the parietal an ossified falx may extend into the cranial cavity, as in the Ornithorhynchus, while the junction of the parietals may be extended upwards into a large sagittal crest, as in many Carnivora, and even in the Gorilla.

21. The development attained by the FRONTAL bone in the human subject is very greatly above the average of man's class, and bears relation to the vast development of his brain. Sometimes, on the contrary, as in the Cetacea, the orbital part may be enormously developed outwards on each side.

The primitive double condition in which, as we have seen, this bone exists in man, very often persists in adult life in other Mammals. It may do so in Apes, though sometimes in that order (e.g. *Pithecia*) not only is it united, but it even develops a median ridge, continuing forwards the sagittal one.

In many Reptiles and Fishes, however, this bone is single, as in the Gecko and the Cod.

Each half of the frontal bone may meet below as well as above, so as to form a complete bony ring, as in the Python.

The external angular process of the frontal may rarely (as *e.g.* in the Horse) join not the malar, but the zygomatic process of the temporal bone.

In the majority of the members of man's class this process joins neither of those bones, but merely forms a freely projecting post-orbital process.

Sometimes it is completely absent, as is the case in several forms, *e.g.* the Tanrecs.

On the other hand, in the Sauropsida, a distinct bone (either temporally as in Birds, or permanently as in Reptiles) extends downwards from the postero-external part of the frontal. This either ends freely, as in most Birds; or it contributes to form a sort of upper zygoma, as in some Parrots and Lizards; or, as in Python, passes downwards to abut against the single zygomatic arch. It is called the *post-frontal.*

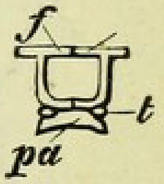

FIG. 98.—DIAGRAM REPRESENTING A TRANSVERSE VERTICAL SECTION OF THE SKULL OF A SERPENT.

f, frontal, meeting its fellow of the other side both above and below in the middle line; *pa*, para-sphenoid; *t*, one of the trabeculæ cranii which persist in serpents, running forwards on each side of the base of the skull.

A bone exists in the skull of osseous Fishes which has often been called the "post-frontal," but which has no relation to that bone of Reptiles, being really an ossification of the ear capsule, and therefore the representative of part of the petrous bone of man.

The superciliary ridges, which in some races of men are much marked, may attain a far greater size, being at their maximum in one of the highest Apes, viz. the Gorilla.

The two sides of the frontal may unite behind the cribriform plate, as is the case in the commonest Monkeys.

The frontals may develop great bony processes, which are the bony cores supporting the corneous sheaths of hollow-horned Ruminants, as *e.g.* in the Goats. They may also periodically develop branched processes, "antlers," as in Deer.

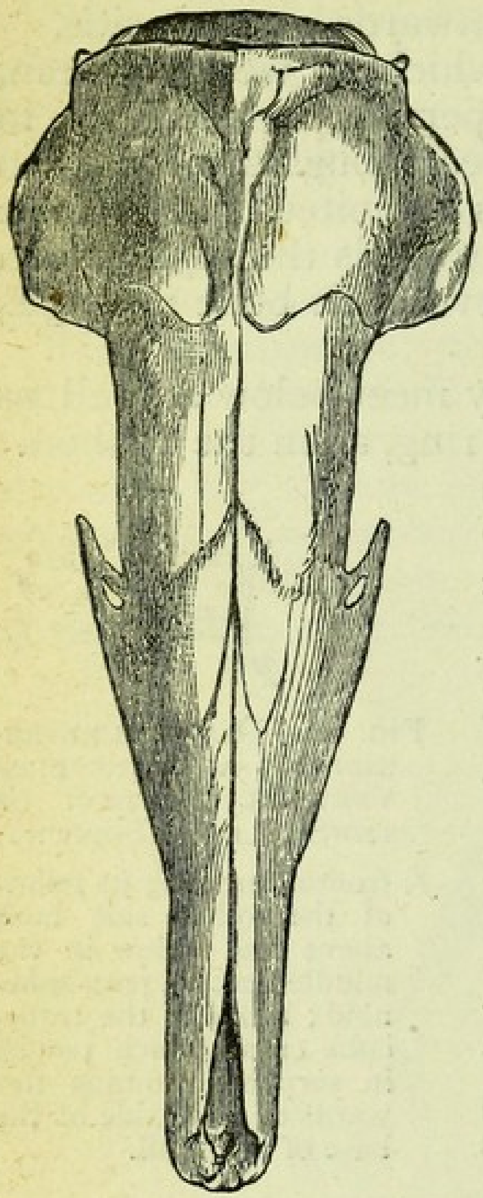

FIG 99.—Upper view of the Skull of the Tanrec, *Hemicentetes;* showing the absence of a zygomatic arch on each side.

These will be more conveniently considered in the Seventh Lesson.

22. The TEMPORAL bone of man is the representative not only of a number of distinct bones in lower animals, but of bones of very different natures both as to origin and function.

What answers to the squamous portion in man, is called the "*squamosal*" in lower animals.

In man it is of greater relative size, and takes a larger share in the formation of the inner cranial wall than is the case in most of his class, though, strange to say, it becomes again relatively larger in one of the very lowest of Mammals, *i.e.* the Echidna.

Below the Mammalia it becomes excluded from all share whatever in bounding the cranial cavity, and may be a mere bar contributing to form the bony scaffolding of the skull, as in Lizards or as in bony Fishes. A portion of it may descend from the cranium altogether, and become a mere part of the gill-cover flap, the pre-operculum.

The function of suspending the lower jaw is one peculiar to this element of the skull in Mammals, while in all Vertebrates below Mammals the squamosal has no part in such an office.

Amongst his own class, man presents a medium development of the glenoid surface, which may be much more concave than in him (as in Carnivora), or much less so (as in Ruminants).

Its antero-posterior concavity is thus most marked in the hard-gripping Badger, where the anterior and posterior bony margins of the glenoid surface are so prolonged that the lower jaw cannot be removed, even from the dry skull, without fracture of one of those osseous processes.

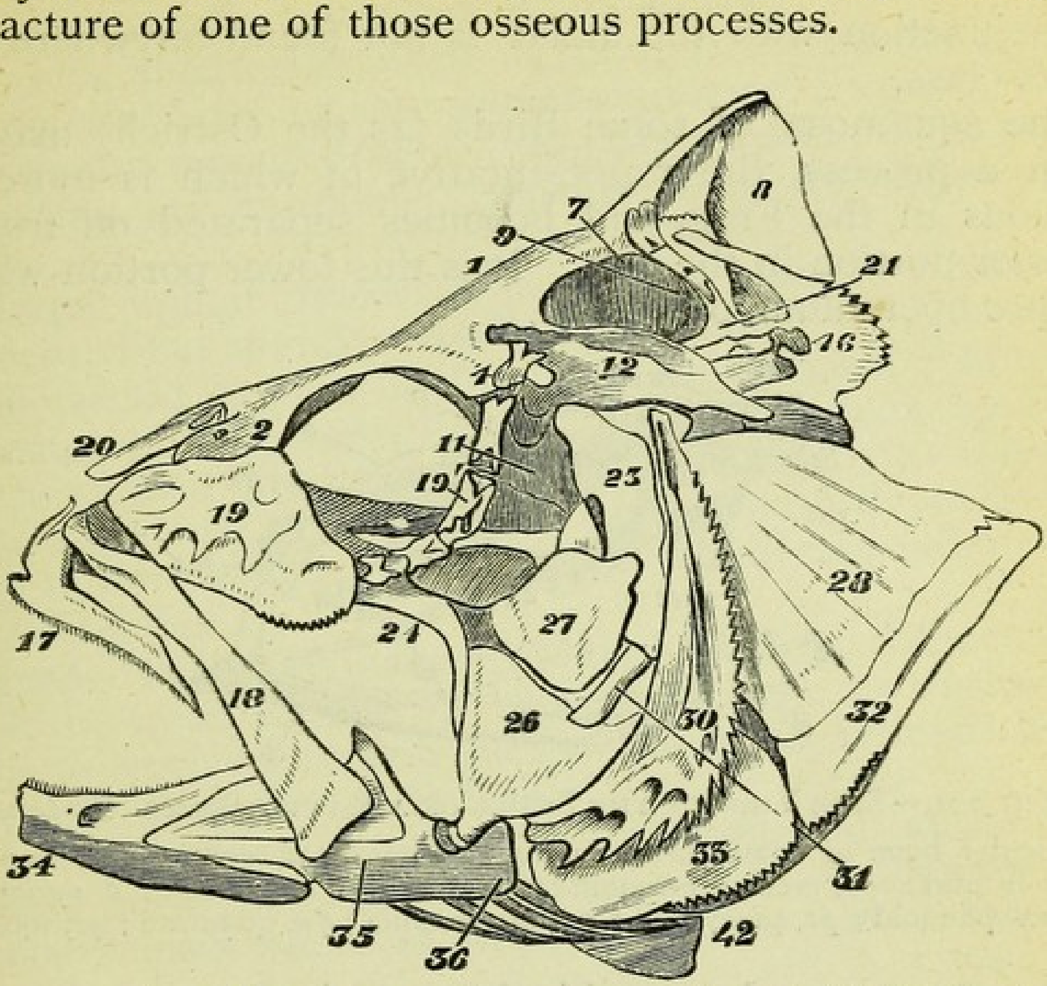

FIG. 100.—SIDE VIEW OF THE SKULL OF A PERCH. (*After Cuvier.*)

1, the frontal; 2, the pre-frontal; 4, the sphenotic; 7, parietal; 8, supra-occipital; 9, exiotic; 11, pro-otic; 12, pterotic; 17, pre-maxilla; 18, maxilla; 19, first sub-orbital bone, or lachrymal; 19′, chain of posterior sub-orbitals; 20, nasal; 21, one of a chain of post-temporal ossicles; 23, hyo-mandibular; 24, ecto-pterygoid; 26, quadrate; 27, meta-pterygoid; 28, operculum; 30, pre-operculum; 31, symplectic; 32, sub-operculum; 33, inter-operculum; 34, dentary; 35, articular; 36, angular; 42, urohyal; 46, post-temporal, or bone connecting scapular arch with skull.

The projecting (zygomatic) portion of the squamous element is constantly present in Mammals, though it may end freely, as in *Centetes* and *Sorex*, or join the frontal instead of the malar, as in the Horse.

It also projects freely downwards in most Birds, but it may (as in some Parrots) articulate with a post-frontal element.

In Reptiles also it may project forward and form a sort of upper zygoma by articulating with the post-frontal, as in some Lizards (e.g. *Sphenodon*, *Cyclodus*), or it may be articulated with the cranium at one end only, as in Python—the other end projecting backwards and slightly outwards, to give additional mobility to the lower jaw.

It may develop, as in Fishes, a post-orbital process of its own.

Its junction with the malar is not found anywhere out of man's class.

The squamosal of some Birds (as the Ostrich) may send down a process, the representative of which is more conspicuous in the Frog, and becomes separated off from the superior portion in the Eft. It is this lower portion which is the pre-operculum of Fishes.

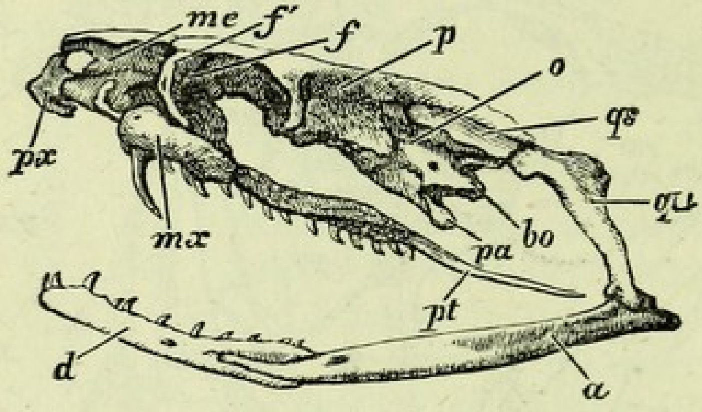

FIG. 101.—SIDE VIEW OF THE SKULL OF A RATTLESNAKE (*Crotalus*).

a, articular bone of lower jaw ; *bo*, basi-occipital ; *d*, dentary ; *f*, frontal ; *f'*, pre-frontal ; *me*, median ethmoid ; *mx*, maxilla ; *o*, pro-otic ; *p*, parietal ; *pa*, para-sphenoid ; *pt*, pterygoid ; *px*, pre-maxilla ; *qu*, quadrate ; *qs*, squamosal.

The petrous and mastoid elements (petro-mastoid) of the temporal bone require a more lengthened notice.

In the first place, it may be observed that the distinctness of these united elements is shown in many Mammals where the petro-mastoid bone remains unanchylosed and separate from both the squamosal and tympanic elements of the temporal bone. This is the case, *e.g.*, in the Pig. It may be united with the tympanic element, but not with the squamosal, as in the Hare and the fully adult Porpoise, being in the latter only united to the rest of the skull by ligamentous attachment.

Still, in all man's class, what we have seen to be the constituent parts of the petrous and mastoid elements always cohere into a single mass before they unite with other cranial elements, while such a complete primitive union never takes place in any Vertebrate not a Mammal.

The very prominent mastoid process of man is peculiar to him, as, though in many other Mammals it is more or less developed, it is generally rivalled or surpassed in them by the elongated process of the occipital bone before mentioned.

Even in the highest Apes the degradation of the mastoid process is remarkable, and bears relation to the absence of an erect posture of the body—a posture which distinguishes man from the other members of his order.

Air-cells which exist, even in man, in the mastoid, extend into the substance of the squamous element in the Gorilla, and sometimes, as in *Macroscelides* and *Pedetes*, the mastoidal air cavities are enormous, causing great projections of the skull.

A large vaginal process is peculiar to man, that part being represented but slightly even in the Gorilla.

The carotid canal is far from being a constant character of the temporal bone, even in Mammals. Often, as *e.g.* in the Cat, the carotid artery may pass through the foramen lacerum posterius, merely grooving very slightly the petrous bone; or much more rarely, as in the Opossum, it may perforate the sphenoid bone.

In most Mammals, except the highest Apes, there is a deep pit on the inner surface of the petrous bone, as in the Hare: this is to receive a certain part of the brain, termed the floccular process of the cerebellum.

The stylo-mastoid foramen is a constant aperture, the seventh nerve passing out through such an opening in the petrous element wherever this is ossified in vertebrate animals.

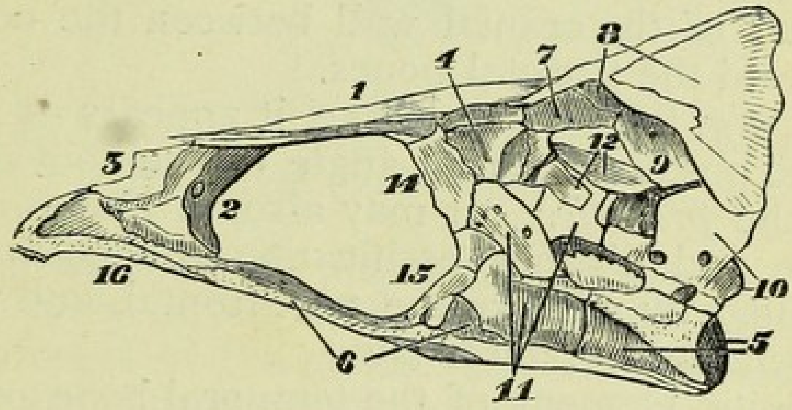

FIG. 102.—VERTICAL, LONGITUDINAL SECTION OF THE SKULL OF A PERCH. (*After Cuvier.*)

1, frontal, ; 2, pre frontal (or lateral ethmoid) ; 3, median ethmoid ; 4, sphenitic ; 5, basi-occipital ; 6, para-sphenoid ; 7, parietal ; 8, supra-occipital ; 9, epiotic ; 10, exoccipital ; 11, pro-otic ; 12, pterotic ; 14, alisphenoid ; 15, pre-sphenoid ; 16, vomer.

But not only the seventh nerve, but the third portion of the fifth also, may perforate the same bone, as is the case in Serpents, in Batrachians, and in many Fishes (*e.g.* the Pike); or it may only notch it, as in Crocodiles and Birds; or it may, as in man, pass altogether in front of it.

The three elements (pro-otic, epiotic, and opisthotic) which, as we have seen, coalesce to form the petro-mastoid part of the temporal bone of man, may be differently proportioned and conditioned from what they are in him.

The *Pro-otic* is the largest and most important element of the three in Vertebrates below Mammals.

It may meet with its fellow of the opposite side below, and thus form part of the inside floor of the skull, as is the case in many Fishes, *e.g.* the Pike.

The *Opisthotic* constantly anchyloses with the lateral part of the occipital before it unites with the pro-otic in all Vertebrates below Mammals. In many forms, *e.g.* the Cod, it never unites with the pro-otic at all.

The *Epiotic* constantly anchyloses, in all Vertebrates below Mammals, with the squamous portion of the occipital bone before it unites with the pro-otic and opisthotic elements.

In Fishes and in Chelonians it preserves its distinctness from the occipital, though in Chelonians it coalesces with the opisthotic.

These three bony barriers protecting the internal ear may be conveniently spoken of as the *periotic mass.*

This mass may have added to it a part which, in some Mammals, appears as a lamelliform expansion, as in the Mole and still more in the Echidna, where it constitutes a considerable part of the cranial wall between the occipital, the squamosal, and the parietal bones.

In Fishes, *e.g.* the Cod and Pike, it appears as a bone projecting at the postero-external angle of the roof of the skull. It is called the *pterotic.*[1] It may also, in Fishes, have added to it a large and distinct ossification, the *sphenotic*,[2] which has been called by mistake the post-frontal, and which takes part in suspending the lower jaw.

The tympanic element of the temporal bone of man may, even in forms so little removed as are the American Apes, be reduced to the ring-like condition which it has in the human infant. On the other hand, in many Mammals, *e.g.* in the Dog and especially *Macroscelides*, it forms a large inflated structure termed a *bulla.* In oviparous Vertebrates it is not represented except by the frame of the tympanic membrane.

The styloid element may be more conveniently treated of under the head of hyoidean structures. It is sufficient to say

[1] Πτέρυξ, a wing.

[2] So called because adjoining the alisphenoid,—by its discoverer, Mr. W. K. Parker, F.R.S., who also discovered and named the "pterotic."

here that it is only found very elongated and anchylosed to the skull in man, though an anchylosed but less elongated one is sometimes found in a species of Baboon.

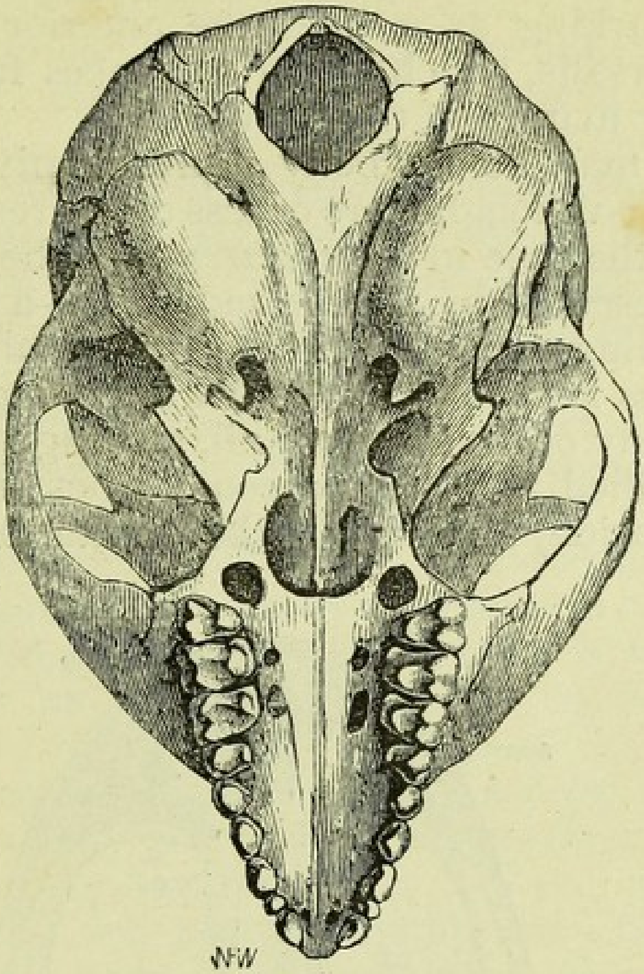

FIG. 103.—Under Surface of the Skull of the Lemur *Microcebus minor*, showing the inflated auditory bullæ (on each side in front of the foramen magnum), and also the defects of ossification in the bony palate.

The tympano-hyal will also be noticed with the hyoidean structures. Only in Mammals, but in them constantly, does it form a process of the skull. Its common form, as in the Dog, is that of a small cylindrical truncated process, between the tympanic bulla and the paroccipital process. In man it is obscured by anchylosis with the styloid process, of which it forms the root.

23. The SPHENOID, like the temporal bone of man, is a highly complex one, as is made evident by what we find in other animals.

The body of the sphenoid is a less constant structure as a distinct bone than might be supposed. On the other hand, that close union between it and the basi-occipital, which in adult man is constant, is rarely found elsewhere. Even the body of the sphenoid itself, in Mammals, is generally formed of two distinct bones, the posterior of which is termed in zootomy the *basi-sphenoid*, while the anterior ossification (in front of the pituitary fossa) bears the name of *pre-sphenoid.*

The basi-sphenoid is a point of very great morphological importance, marking as it does the anterior termination of the chorda dorsalis, which never advances further forwards than the hinder margin of the sella turcica.

Now, there may be no bony representative of the basi-sphenoid at all—although more or less of the rest of the skull be ossified—as is the case in *Lepidosiren* and the Amphibia ; or it may be represented by a mere rudiment—a little Y-shaped bone, only forming part of the front of the pituitary fossa, as in the Pike. Thus it need form no part of the inside floor of the skull, nor yet any of the basis cranii, although the last-named part be well ossified, as it is in osseous Fishes and Batrachians. In the Ichthyopsida, in fact, only the median bony investment

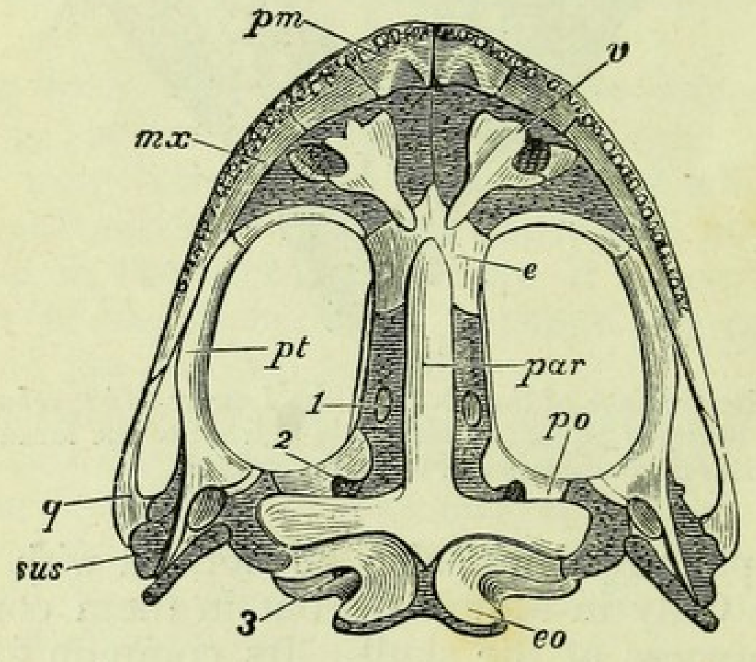

FIG. 104.—UNDER SURFACE OF THE SKULL OF A FROG. (*After Parker.*)

e, girdle-bone ; *eo*, exoccipital ; *mx*, maxilla ; *par*, paroccipital ; *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 ova e ; 3, condyloid foramen.

of the basis cranii is a special membranous ossification, termed the *para-sphenoid*, which extends, both backwards and forwards, far beyond the limits of the basi-sphenoidal region. This "membrane" bone is also large and conspicuous in Snakes (which have the body of the sphenoid in a cartilaginous condition), but it seems to be representated in man, if at all, only by the "lingulæ sphenoidales."

The basi-sphenoid itself, on the other hand, may be hypertrophied, sending out a long rostrum in front and lateral processes, as is the case in Birds; and in man's own class it may develop descending and diverging processes, as in the Hedgehog, Centetes, and the Porpoise. In the first two we find a hemispherical depression on the under surface of the sphenoid body, reminding us of the sella turcica on its cranial surface.

The pre-sphenoid attains not only more distinctness, but a much greater length, in Mammals generally than in man. In all lower forms, however, it is more or less rudimentary or absent: absent, *e.g.*, in Batrachians; rudimentary in Birds and some Fishes, *e.g.* the Carp and Salmon.

The basi-sphenoid may be directly perforated by the internal carotid artery, as is the case in Marsupials; or the two carotid canals may unite in it, as in Birds.

The posterior boundary of the sella turcica, with its clinoid processes, is more prominent in man than in almost any other animal, and the depression of the sella is very marked in him. It may be quite indistinct, as in Marsupials and Batrachians.

The sella may, on the contrary, be a deep and sudden depression without any prominent margins directed upwards, as in many Fishes, *e.g.* the Pike.

A singular and unexpected function may be performed by the cartilaginous body of the sphenoid, as in the Pike and in very many other Fishes, where it forms part of the roof of a large conical excavation of the basis cranii, in which excavation the muscles of the eyeball take their origin.

The greater wings of the sphenoid bear in zootomy the name *alisphenoid.* They form a part of the cranial side-wall which is very generally present in an osseous condition, though not so in Chelonians or Batrachians. Alisphenoids are invariably developed in all the members of man's class (Mammalia), and also in Birds and Crocodiles. Usually they take a relatively greater share in the formation of the cranium than in man, whose skull-roof bones are so enormously expanded. This is notably the case in Marsupials and some Insectivora, where they extend far back and form the anterior part of the auditory bullæ, and in the Kangaroo even touch the paroccipital process.

The orbital plate of this bone is not developed in Mammals below man's own order, but its homologue is developed in some Birds, e.g. *Accipiter* and *Strix;* and it is possible that it may also be represented by the sphenotic, which in bony Fishes unites with the pterotic to furnish the point of suspension for the lower jaw.

The so-called external pterygoid process of man is really but an outgrowth of the alisphenoid, and must be considered with it. This part is absent in all animals below Birds, and in Birds where it exists, *e.g.* in the Finches (*Fringilla*), it is represented by but a single or double ridge.

In Mammals generally, however (except the Echidna), it is present, and more or less as in man, though mostly it is larger and less deep vertically.

The external carotid artery may pierce the root of this part (as in the Dog), forming thus a special bony channel called the *alisphenoid canal*. The third branch of the fifth nerve may pass more anteriorly with regard to this bone than in man, as is the case in the Sheep. On the other hand, it generally passes out altogether behind it. A vidian canal is often much more conspicuous than in him, *e.g.* in the lower Apes.

A distinct foramen rotundum is often present and often absent. In the latter case, the second branch of the fifth nerve passes out through the sphenoidal fissure, as *e.g.* in the Hare, Squirrel, and Stag.

Each of the lesser wings of the sphenoid is termed in zootomy an *orbito-sphenoid*, and in some forms, *e.g.* in Ruminants, the proportion they bear to the alisphenoid is the reverse of that which obtains in man, so that the application to them generally of the name they bear in anthropotomy, "lesser-wings," would be manifestly out of place. These bones are constantly present in man's class, but, unlike the alisphenoid, are often absent in the class of Birds, though present in many kinds (e.g. *Accipiter* and *Tinamus*). They are mere rudiments in most Reptiles—often altogether absent—though they may be developed in Lizards. In Batrachians they may be well developed, or coalesce (as in Frogs and Toads) with the ethmoid in a way to be described in treating of that bone. In Fishes they are generally absent, but may be well developed, as in the Carp, where however they form one bone with the pre-sphenoid.

Occasionally, as in the Hare, they may be so disposed as to constitute a median, interorbital septum, the two optic foramina having become merged one in the other.

The optic foramen may be excessively minute, as in some Insectivora, and there may be a foramen passing from orbit to orbit beneath it, as in *Macroscelides*.

The internal pterygoid processes of man represent very important and constant parts of the cranium, which exist in all classes down to and including bony Fishes.

The share which they take in man in bordering and bounding the posterior nares is by no means their normal office in Vertebrates generally. In Birds and in all lower Vertebrates (except the Crocodiles) they have no connexion with these apertures, but are quite posterior to them, serving to connect the hinder part of the palatine with the point of suspension of the lower jaw, and, except in Fishes, have also a connexion with the sphenoidal region of the basis cranii.

Sometimes, as in Serpents, these bones may be very movable.

In certain forms, *i.e.* in the Crocodiles, Ant-eaters (see Fig. 117), and in the Echidna, these bones may develop horizontal plates, which form the posterior part of the bony palate. So that, in these animals, the posterior nares are bounded by the pterygoids, both laterally and inferiorly. The pterygoid may be swollen and bullate, as in the Mole and in some Sloths.

The internal (but not the external) pterygoid processes really belong, not to the cranial bones proper, but to those of the face.

In Lizards, a peculiar dismemberment of the pterygoid,

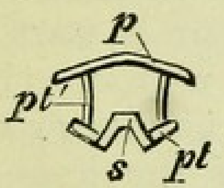

FIG. 105.—Diagrammatic Vertical, Transverse Section of the Skull of a Lizard, showing the *columellæ* ascending from the pterygoid bones to the parietals.
p, parietal; *pt*, pterygoid bone; *pt'*, columella, or dismemberment of pterygoid; *s*, basi-sphenoid, diverging processes of which join the two pterygoids.

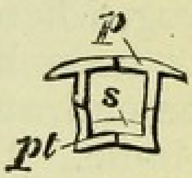

FIG. 106.—Diagrammatic Vertical, Transverse Section of the Skull of a Chelonian, showing the meeting on each side of upward processes of the pterygoids with downward processes of the parietals.
p, parietal; *pt*, pterygoid; *s*, basi-sphenoid.

called the *columella*, may ascend and join the parietal. In Chelonians a corresponding process of the pterygoid may ascend and meet a corresponding downwardly directed process of the parietal.

24. The ETHMOID is another complex aggregation of elements which are distinct in lower animals. In man's class,

however, it remains, for the most part, pretty much as it is in him.

The os planum, in that it is large and conspicuous and situated on the inner wall of the orbit, presents conditions which man shares with the Apes, but which are very rare in other forms. In some Cats, however, it appears in the orbital between the lachrymal, frontal, and palatine bones.

The part corresponding to the os planum of man exists within, and hidden by, the maxillary plate in other mammals; but it may be represented by a cartilage or cartilages, as in birds.

The lateral masses of the ethmoid appear in the form of distinct bones (*pre-frontals*) in Crocodiles, Lizards, and osseous Fishes. They may, as in the Chameleon, extend on to the maxilla, so shutting out the nasals from the anterior nares; and in some Chameleons they may be prolonged so as to help to form two great bony horns projecting forwards from the muzzle.

The median ethmoid is constantly present in a cartilaginous or osseous condition as part of the internasal septum. Even in fishes it is generally more or less ossified. It is possible that it may appear on the external surface of the skull in Mammals, as in the Seal *Monachus*. It does so in Fishes (*e.g.* Carp and Tench), and at least in some Birds.

A peculiar condition of the parts may exist, such as is found in the Frog, where the ethmoid forms (or is part of) a bone which has been likened to a dice-box with a vertical partition at one end, and has been named by Cuvier *os en ceinture*, or girdle-bone. It consists probably of the lesser wings of the sphenoid united to the median and parts of the lateral ethmoid.

The ethmoidal cells of the lateral ethmoid may attain a much greater size and complexity than in man, as we see in the Dog and very many Mammals. On the other hand, these parts may utterly and entirely abort, as in the Porpoises.

A cribriform plate is common to, and generally large in man's class; it may be wanting, as in the Porpoise, or enormous, as in the Echidna.

The crista galli is more defined in man than generally in Mammals, but it may be very large, as in some Seals and Ungulates.

In certain Seals again, as in *Cystophora*, and in the Tapir, the median ethmoid may extend forwards beyond the anterior end of the nasals.

The lower *turbinals* may be noticed next after the ethmoid, being of cognate nature.

The simplicity of their structure in man would hardly lead us to anticipate the size and complexity which they may attain in some animals, *e.g.* in the Badger and the Sheep. They may, on the contrary, abort altogether, as is the case in the probably smell-less Porpoises. In the Elephant they are but rudimentary.

In Fishes these bones are quite absent, and in Batrachians are represented by a mere cartilaginous rudiment.

In Reptiles they are simple, and quite, or almost entirely, cartilaginous, though with a slight bony outgrowth in the Crocodile. But in Birds they may be represented by two or three insignificant ossifications.

25. As to the MAXILLARY bone, we will consider first the whole of it except that small portion in which the incisor teeth are implanted; such whole being the bone called "the maxillary bone," or "maxilla," in other vertebrate animals generally.

In that it presents an external facial part, an internal nasal part, an inferior palatine part, and a superior orbital part, the maxillary bone of man agrees with that of almost all Mammals.

In lower forms, except the Crocodilia, the maxilla is much smaller, and it may be a mere filiform rudiment, as in Siluroids, or abort altogether, as in the *Siren* and the Myxinoids.

It may, on the contrary, be represented by several distinct and separate bones placed in a series along the jaw, as is the case in the bony Pike (*Lepidosteus*).

Very often its length may greatly exceed its height, as in the Great Ant-eater and in Cetaceans.

In that the bone bears teeth, we have in man a character which is by no means universal in his class, as *e.g.* in the Ant-eaters, Whalebone Whales, and the Echidna, the maxilla, like every other bone of the skull, is edentulous. The same is the case in Birds and Tortoises, but in many Fishes (as *e.g.* the Cod) the maxilla may be edentulous, while nevertheless other bones of the face bear teeth.

The facial surface of the bone is occasionally much swollen out, as in the Baboons. Sometimes, as in the Paca, this surface is rough and pitted, while the bone is excavated by a large fossa which opens on the inner surface. Again, the facial surface may be very imperfectly ossified and may present a reticulated structure, as in the Hares.

The infra-orbital foramen may be multifold, as in most Apes, or may be enlarged into an enormous aperture, transmitting part of the masseter muscle, as is the case in the Porcupine and some other Rodents. This great opening may exist, and yet the true infra-orbital canal be defined by a bony lamella, as in the genus *Lagostomus*.

The palatine plate of the maxilla exists in all Mammals and in Crocodiles, yet even in Mammals it may occasionally be excessively reduced, as in the Hare. In the lower classes it is wanting.

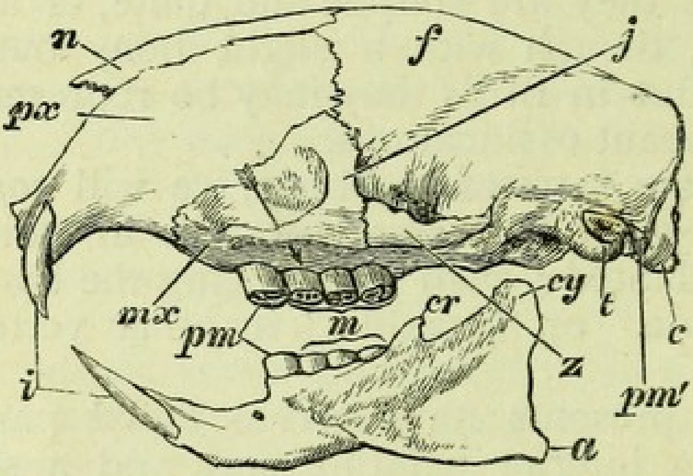

FIG. 107.—SIDE VIEW OF THE SKULL OF A PORCUPINE (*Hystrix cristata*).

a, angle of mandible ; *c*, occipital condyle ; *cr*, coronoid process of mandible ; *cy*, condyle of mandible ; *f*, frontal ; *i*, incisor teeth ; *j*, ascending branch of maxilla enclosing the enormous infra-orbital foramen, the course of the masseter muscle through which is indicated by an arrow ; *m*, molar teeth ; *mx*, maxilla ; *n*, nasal ; *pm*, premolar teeth ; *pm'*, paramastoid process ; *px*, premaxilla ; *t*, tympanic bone ; *z*, zygomatic arch—the part formed by the malar.

The maxilla may acquire an enormous size, and overlap and almost entirely conceal the frontals, as in Cetaceans.

Sometimes, as in *Chiromys*, the maxilla is shut out from articulating with the nasal bone by the extension upwards to the frontal of that separate element of the human maxillary bone which is next to be noticed. The latter element may, sometimes, be separated by an interval from the part corresponding to the rest of the human maxilla,—as in the Three-toed Sloth.

Occasionally (as in some specimens of *Macacus nemestrinus*, and in the Gavial) the maxillary bone may join its fellow of the opposite side above the nasals, thus separating the latter from the frontals.

Occasionally, as in some Chameleons, the maxilla may project freely forwards as a great bony horn at the front part of the face.

The second element of the human maxillary bone—namely, that in which the incisor teeth are implanted—is termed in zootomy the *pre-maxilla.* Its existence in man, even at birth, is obscured (except on the surface of the palate) by anchylosis, and masked by the extension over it of a delicate plate, or lamina, of the first and far larger portion of the maxillary bone. This lamina is wanting in all other animals, and even in the Apes the maxillo-premaxillary suture is for a long time or permanently very evident on the face.

A pre-maxilla is almost a constant element in an osseous skull; nevertheless, in some Bats and Shrews (e.g. *Crocidura*) it seems to abort. It may attain a vast size, as in Birds, where it forms the greater part of the upper half of the beak, and reduces the part representing the other element of the human maxillary to insignificance. Generally double in Batrachians, apparently always so in Fishes, a single median ossification may nevertheless, as in Serpents, represent the pre-maxillæ of both right and left sides conjoined.

In man's class the pre-maxilla varies greatly in size in different animals, and this independently of the development both of the muzzle and of the teeth; for the Ant-eater and the Whale are both edentulous, and both have an enormously produced muzzle, yet, while in the former the pre-maxilla is extremely small, in the latter it is very largely developed. A nasal spine is very rare, but may exist below man, as in *Pedetes* and the Walrus.

Generally the development of the pre-maxilla is related to that of the incisor teeth, which are defined by the fact of their being implanted in it, though when they are very large, as in Rodents, their roots may extend backwards into the parts which represent the first-described element of the maxillary bone of man.

In some Bats (e.g. *Vespertilio noctula*), and the Ornithorhynchus, we find the pre-maxilla separated by an interval from its fellow of the opposite side. On the contrary, these may be united not only below but also above the anterior nares, as in the Gavial and Echidna. Again, they may be united in the middle line, but altogether separated from the first-described element of the human maxillary bone, as in the Three-toed Sloth and in Serpents.

In this latter case we have normally existing that occasional abnormal arrest of development in man, which we call hare-lip."

26. The MALAR bone is almost at its maximum of relative

development in man, and only in Mammals and the Crocodile does it approximate to the condition it attains in him. It is a less constant bone than the maxillary, as it is absent in some Mammals, e.g. *Centetes* and *Manis*, also in Batrachians, Serpents, and generally in Fishes.

It may be merely a delicate spiculum of bone, helping to form the zygoma, as is the case in Birds.

In none but man and Apes does the malar develop the orbital plate, and generally in Mammals it does not even meet the frontal outside the orbit; and when the orbit is encircled by bone, the malar may be separated from the frontal by the intervention of the zygomatic process of the temporal bone, as in the Horse.

Processes may be developed which do not exist in man, as is the case in the Sloths, where there is both an ascending and a descending process, but no process to form a junction with the zygomatic portion of the temporal bone.

There may be a considerable perforation in the malar, as in some Lemurs and Insectivora.

Sometimes, as in the Porpoise, the malar may be double—the zygomatic portion being a separate ossification from its front part.

27. The NASAL bones are more constant elements of the bony skull than are the malar bones, as, except in most Chelonians, they seem to be constantly developed. There may be a pair of them, as in man (and this is the general rule), or there may be but a single median ossification, as is the case in Varanian Lizards. Even in man's class (Mammalia) they may be represented by a single bone through their early anchylosis, as is the case in *Centetes*, *Spalax*, and the Orang.

The very extremes of development of these bones are also to be found in the same class, as in the last-mentioned form (the Orang) they all but abort, and in the Porpoises they form small rounded masses, each lying in a concavity on the frontal bone, and not at all roofing over the nasal passages. On the other hand, in the Porcupine they are of enormous size, in fact the largest of the cranial bones.

In the Porpoises the two nasals may cease to follow the general rule among Mammals, of joining each other. In Fishes they may lie wide apart. They may be shut out from bounding any part of the anterior nares, as in the Chameleon, where the pre-frontal extends to the maxilla, as before mentioned.

28. The LACHRYMALS may be altogether absent, or may

have a different function from that they have in man; or having the same function as in him, they may be considerably increased in size and importance.

They may be absent as distinct bones even in man's class —especially in forms which pass a large part or the whole of their lives in water, and where the secretion of tears is superfluous.

Thus they are absent by anchylosis with the malar in the Dolphins, and are wanting altogether, unless early anchylosed with the maxillary or malar, in the Seals and Pangolins. On the contrary, though very small, they are present in the Elephant and Sirenia, but in an imperforate condition.

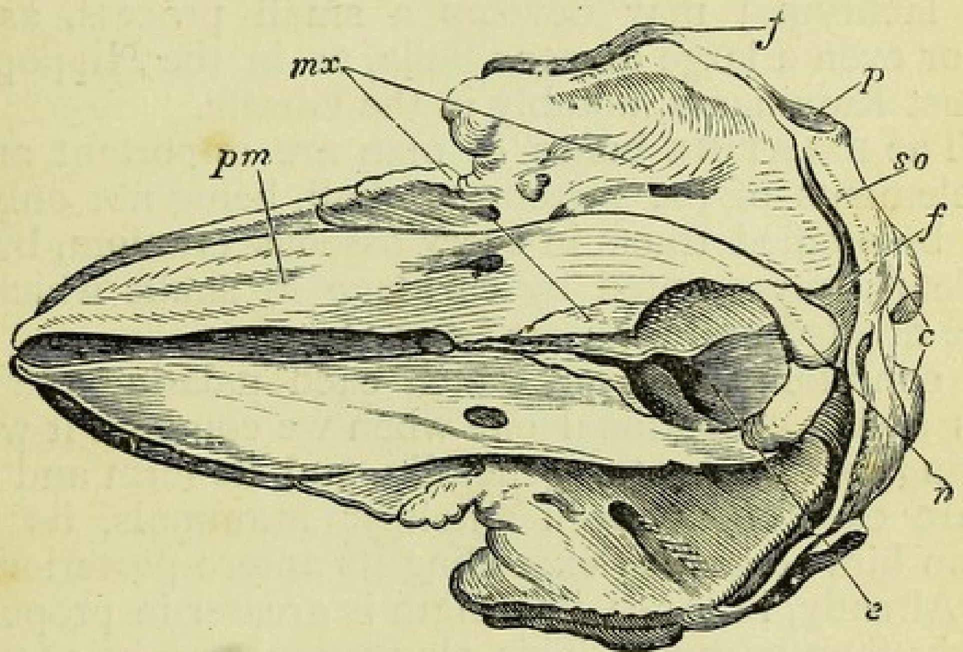

FIG. 108.—UPPER VIEW OF THE SKULL OF A DOLPHIN (*Delphinus globiceps*). (*After Cuvier.*)

c, occipital condyles; *e*, median ethmoid in nasal fossa; *f*, frontal overlapped by *mx*, maxilla; *n*, nasal; *p*, parietal, driven down quite to the side of the skull; *pm*, pre-maxilla (here enormous); *so*, supra-occipital.

They are present and of good size in many Fishes (e.g. *Pristipoma*), where each lachrymal constitutes the first of a chain of suborbital scalelike bones, which extend beneath the orbit from before backwards. In Fishes, of course, there is no lachrymal foramen.

These bones appear to be absent altogether in Batrachians, and sometimes in Birds, though present, and sometimes large, in Reptiles (*e.g.* Chelonians).

In that the lachrymal is confined to the orbit, man differs from most of his own class, except the Apes; even in animals so high up in the scale as Lemurs it not only extends on to the cheek, but the lachrymal foramen is placed there.

Often it is of great size, as in the Hare, Ant-eaters, and Armadillos, or, as in the Deer, not only largely developed, both in the orbit and on the cheek, but also presenting a peculiar fossa destined to receive and shelter a special glandular structure.

This bone may join the malar, as in the Squirrel and the Hog. Its junction with an os planum is a very exceptional condition, though found in Apes as in man.

It may join the palatine bone in the orbit, as *e.g.* in the Rhinoceros.

It may even complete the sub-orbital foramen superiorly, as in *Dolichotis.*

The lachrymal may develop a small process, as in the Hare, or even a large osseous bulla, as in the Hippopotamus and most Ruminants, notably in the Giraffe.

29. The PALATINE bones of man are important and constant elements of the vertebrate skull, being not only represented by ossified tracts in every osseous cranium, but being also clearly represented by cartilage in skulls which never become divided into separate bony elements.

The condition, however, which each palatine presents in man is a very exceptional one when we compare it with that prevailing in Vertebrates generally, and its form and proportions are exceptional even amongst Mammals, its vertical extent in him so greatly exceeding its antero-posterior dimension. Already, in Apes, its length is greater in proportion to its height than in man. This elongation may be enormously increased, as in the Great Ant-eater—though the prolongation of the muzzle does not necessarily carry with it a similar increase in length of the palatine, as we see in the Dolphin, *Globicephalus*, where it is comparatively short.

That the posterior margin of the palate bones should form the antero-inferior border of the posterior nares is a character which man shares with most of his class, and with no other. In some Mammals, however (as we have seen), it is the pterygoids which perform this function, as in the only Sauropsidans (Crocodilia) having a palate with a solid bony roof like man's.

It is the rule, however, that the anterior margin of the palate bones forms the postero-inferior margin of the posterior nares, as we find to be the case in Birds, non-crocodilian Reptiles, and Batrachians.

This difference of position in the palate bones is owing to the fact that the horizontal, or palatine, plate, and the greater part of the perpendicular plate, are parts which have no bony representatives in non-mammalian Vertebrates, with the exception of the Crocodiles. Only that part of each palate bone which connects the body of the sphenoid with the vomer and upper-maxillary bone (*i.e.* the sphenoidal and orbital processes) is represented by the palatine bones of such non-mammalian Vertebrates.

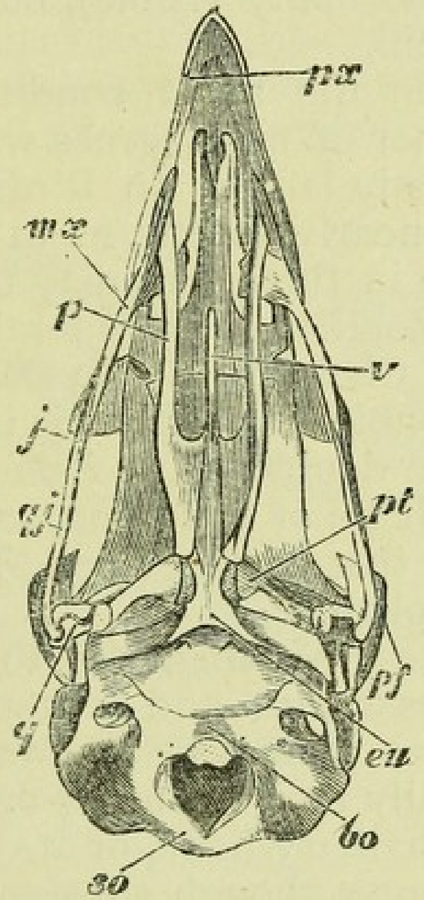

FIG. 109.—UNDER SURFACE OF A FOWL'S SKULL. (*After Parker.*)

bo, basi-occipital; *eu*, points just in front of the anterior opening of the Eustachian tubes; *j*, malar; *mx*, maxillary bone; *p*, palatine bone; *pf*, post-orbital process; *pt*, pterygoid; *px*, pre-maxilla; *q*, quadrate bone; *qj*, quadrato-jugal; *so*, supra-occipital; *v*, vomer.

In almost all those Fishes which have no osseous skull the palate bones are represented by the anterior part of that cartilaginous bridge, or flying buttress, which proceeds from within the front of the mouth backwards and outwards towards the point of suspension of the lower jaw, and which in Sharks supports teeth and is called the upper jaw.

Sometimes the horizontal plate has large defects of ossification, as in many Marsupials and the Hedgehog.

Often in Mammals the palatine may directly join the frontal in the orbit, as in the Hog, *Lemur*, and *Pteropus*. It may join the lachrymal, as in the Dog. It may extend in the orbit between the lesser wing of the sphenoid and maxillary, and between the frontal and the lachrymal, as is the case in *Dolichotis*. It may or it may not take a share in the formation of the pterygoid fossa. It appears even to form part of the margin of the optic foramen in the Echidna.

30. The VOMER again is a bone of remarkable constancy. It is much less concealed by other bones in Vertebrates generally than in man, and may appear not only in the palate (where it is indeed normally visible), but also externally on the surface of the skull.

In the fact that in the adult condition it is a median, azygos bone, the vomer of man agrees with that of all Mammals, where it is mostly large. In Birds it may be large, as in the Ostriches, or nearly absent, as in the Pigeons. It is almost always single in them, but may be double, as in the Woodpeckers. In Reptiles it is generally double, but may be single, as in the Chelonians. In Batrachians it is invariably large and double. In Fishes it is large and single in nearly all, but may be double, as in *Lepidosteus* and *Sudis*.

In Mammals the shape of this bone, as might be expected, varies generally with that of the face. Thus it is extremely elongated in the Dolphins.

In all above Fishes it contributes to form the partition between the nasal passages, and (except where the facial bones develop palatal plates, as in Mammals and Crocodiles) borders internally their posterior openings.

31. The inferior maxillary bone, or MANDIBLE, of man is a very characteristic bone, though substantially agreeing with that of other Mammals.

It bears, however, a double relation to parts we find in lower animals. For, while inasmuch as it forms the whole lower jaw it of course agrees with, and answers to, the whole lower jaw of each bird, reptile, and fish ; yet in development and essential nature, it corresponds with a certain portion only of the lower jaw of each of these animals.

Thus it is possible for the part answering to the whole lower jaw of man (*i.e.* the bone called "dentary") not to articulate directly with the cranium, but to be connected with it by a whole series of intermediate parts, as is the case in all Vertebrates below Mammals, and especially in osseous Fishes.

We may find, as in the Sauropsida, an actual lower jaw consisting of several distinct bones (dentary, angular, surangular, coronoid, splenial, and articular) suspended from the skull by a single bone—the os quadatrum ;—or we may find, as in osseous Fishes, the actual lower jaw, consisting of a dentary and other bones, suspended from the side of the skull by the intervention of more than one bone.

In the last-named group the lower jaw is suspended from elements of the ear capsule (viz. the sphenotic, pterotic, and pro-otic) by a bone called the *Hyomandibular*, and by other bones the lowest of which is termed the *Quadrate*, with which the uppermost part of the lower jaw articulates. The bones from the hyomandibular to the quadrate (inclusive), or the cartilaginous parts which in some forms may represent these, are collectively termed the *suspensorium*.

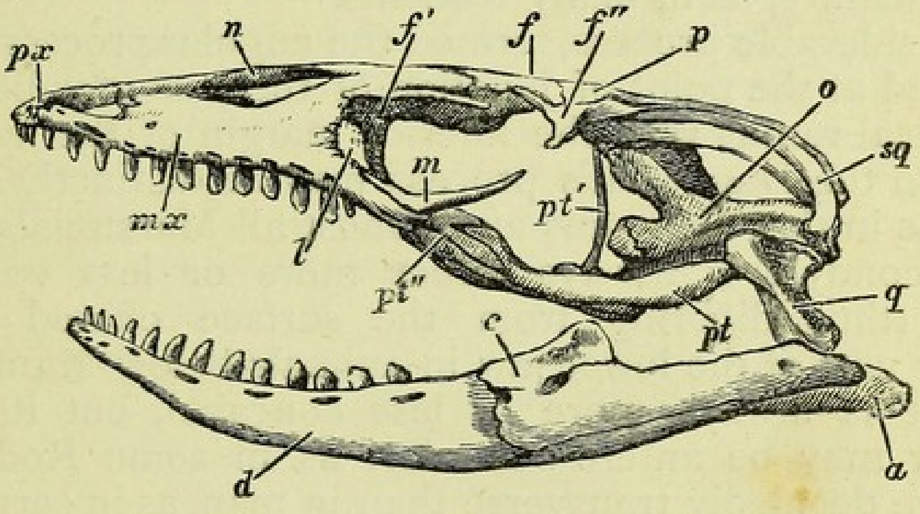

FIG. 110.—SIDE VIEW OF THE SKULL OF A LIZARD (*Varanus*).

a, articular bone of mandible; *c*, coronoid bone of mandible; *d*, dentary; *f*, frontal; *f'*, pre-frontal; *f''*, post-frontal; *l*, lachrymal; *m*, malar; *mx*, maxilla; *n*, nasal; *o*, pro-otic; *p*, parietal; *pt*, pterygoid; *pt'*, columella, or dismemberment of pterygoid; *pt''*, os transversum; *px*, pre maxilla; *q*, quadrate bone; *sq*, squamosal.

A lower jaw, however, may be entirely and completely absent, as is the case in the Lamprey.

In forms in which the skull is not osseous (as the Sharks) the mandible is represented by cartilage.

Wherever below Mammals the skull is ossified, the lower jaw consists of a bone representing the lower jaw of man and Mammals, together with three or four other bones forming with it the actual ramus on each side; and, in addition, there is a distinct part by which this complex ramus articulates with the suspending bone or bones which sustain it.

This articular part, with the suspending bone (called the "quadrate" in Birds and Reptiles) or bones (of which there may be several, as in Fishes), all taken together, answers to parts which are not commonly reckoned as portions of the skeleton in man, namely to parts of the internal ear, *i.e.* to certain of the auditory ossicles, as we shall see more distinctly when we come to treat of the organs of sense.

Confining ourselves to man's own class, his mandible appears to be well developed, but the form and proportion of its parts may be very different from what we see in him.

Thus there may be, as in the Great Ant-eater and Cetaceans, no representative of the ascending ramus; or it may be very low, as in most Rodents, *e.g.* the Porcupine.

The coronoid process may be much developed, rising greatly above the condyle, affording attachment to the voluminous temporal muscle, as in the Dog; or it may be low or rudimentary, as in many Rodents.

A considerable process, termed the angular process, may be developed at the point of junction of the posterior borders of the vertical ramus with the inferior margin of the horizontal one, as in the Dog. This process may be distinctly bent inwards, as in the Opossums and almost all Marsupials.

The condyle is always either more or less convex or flattish (thus differing from the surface offered by the articular part of the lower jaw in animals below Mammals, in which it is always more or less concave), but its longer diameter may be antero-posterior, as in some Rodents, or still more decidedly transverse than in man, as in carnivorous animals, where the movement of the jaw is vertical and not to and fro,—whether from before backwards, as in Rats, Rabbits, &c., or from side to side, as in Ruminants.

Mostly in Mammals the lower jaw continues throughout life to be made up of two bones articulating at the symphysis by suture—as in the human infant at birth.

The symphysis generally inclines from above downwards and backwards, and only in one Ape (the Siamang Gibbon) is there a chin as in man.

The symphysis may be exceedingly narrow, as in the Ant-eater and Porpoise. It may be very elongated but horizontal, as in the Cachalot. The two rami may be each nearly straight, or each may be strongly curved outwards, as in the Whalebone Whales.

The symphysis may be narrow and grooved above so as to give it the appearance of a spout, as in the Elephant, or it may be extraordinarily produced downwards, as in the Dugong.

The entrance of the dental foramen may be exceedingly capacious and funnel-shaped, as is the case in the Dolphin.

The mandible may be directly connected with the neural spines of the anterior (most pre-axial) vertebræ by a very strong ligament which prevents the mouth from being widely opened. This is the case in the Eft *Desmognathus.*

32. That very subordinate bone of the human skeleton, the OS HYOIDES, or tongue-bone, is but a feeble rudiment of skeletal structures of great size and functional importance in the lower Vertebrates. Even less than the temporal bone is it capable of revealing its true nature when studied in man alone.

Small, however, and subordinate as is the os hyoides in him, it may yet be more rudimentary still. Thus osseous parts may be entirely absent, and only represented by two delicate cartilages, as is the case in Serpents.

Throughout man's class we find a substantially similar condition to that which exists in him. That is, we find a body and a pair of cornua, and almost always a pair of cornicula, but the proportions of these parts one to another, and their degree of segmentation, vary.

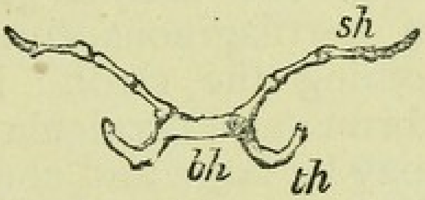

FIG. 111.—Hyoid of a Flying Fox (*Pteropus*), showing the much greater length of the cornicula than of the cornua.

bh, body of the hyoid; *sh*, corniculum divided into three segments—stylo-hyal, epi-hyal, and cerato-hyal; *th*, the cornua of the os hyoides, or thyro-hyal.

(*From Flower's* "*Osteology.*")

Thus the cornicula may abort altogether, as in some Apes. Or they may be large, and represented by three distinct ossifications, named respectively (from above downwards) *stylo-hyal*, *epi-hyal*, and *cerato-hyal*, as is the case in the Flying Fox and in the Dog. These cornicula are normally connected with that process of the under surface of the petrous portion of the temporal bone which has been named the tympano-hyal. The lowermost of these three pieces may send out a process and meet its fellow of the opposite side in front of the body of the bone, as is the case in the Hyrax.

The cornua are more constant in the degree of their development in Mammals. They may be of large size, as in the Thylacine, but never present the segmented condition we so often find existing in the cornicula. They are perhaps at about their maximum of relative size among Mammals, in the Horse.

The body of the hyoid may be in quite a rudimentary condition, as in the Sheep, or swollen and inflated to an enormous relative size, as in the Howling Monkey. It may develop in front a long, median, projecting process, termed a *glosso-hyal*, as in the Horse, which in man is only represented by the vertical ridge on the anterior convex surface of the body of the os hyoides.

When we descend below man's class we may find (*e.g.* in Birds) that the cornicula more or less abort, while the cornua are very long and slender. A glosso-hyal may not only extend forwards from the basi-hyal, but another azygos median part (the *uro-hyal*) may extend backwards from the basi-hyal.

A most unexpected condition may exist, as we see by the Woodpeckers, in which both the elongated cornua curve over the back part of the cranium, and are together inserted just above and behind the right nostril !

In Reptiles we may (as in the Crocodiles) find a cartilaginous body together with one pair of cartilaginous cornua, and these not joining the skull. But generally both cornua and cornicula are developed, and may be large and complex, as in the true Lizards, and the glosso-hyal may be enormous, as in the Chameleon. When, however, we descend to the class Batrachia we begin to perceive the full significance of the hyoidean cornua, and this by means of the transformation undergone by the Frog in its passage from its larval (and fish-like) state as a tadpole to its adult condition.

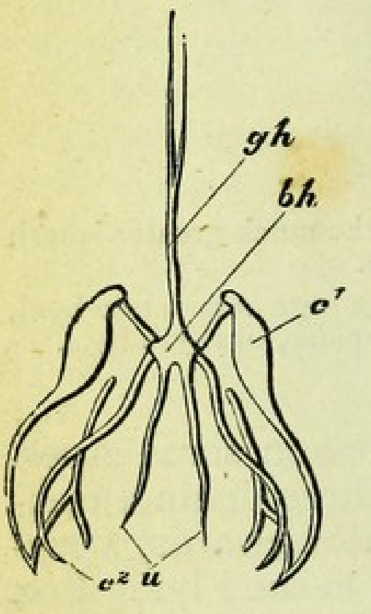

FIG. 112.—HYOID OF A LIZARD—*Lacerta*. (*After Cuvier.*)

bh, body of the hyoid : c^1, corniculum ; c^2, cornua ; *gh*, glosso-hyal ; *u*, uro-hyal.

In the fully-developed state the os hyoides of the Frog consists of a body with a pair of cornua and a pair of cornicula. But the process of development shows that the pair of cornua are the last rudiments and relics of those cartilaginous arches which exist on each side of the neck in the larva and support the gills.

These cartilaginous gill-arches of the tadpole evidently answer to the great cartilaginous branchial (or gill) arches[1] of the Sharks, and to the bony branchial arches of the osseous

[1] For further details concerning these arches see Lesson XII.

Fishes. These branchial arches extend on each side of the throat upwards towards the spine, and support the gills on their inner sides. Other cartilaginous arches which were spoken of in the Second Lesson as existing in the Lamprey and some Sharks, may support the outer sides of the gills. The branchial arches become successively smaller posteriorly, or as we recede from the head. Thus we see what numerous large and important parts of the lowest Vertebrates are rudimentarily represented by the human hyoidean cornua.

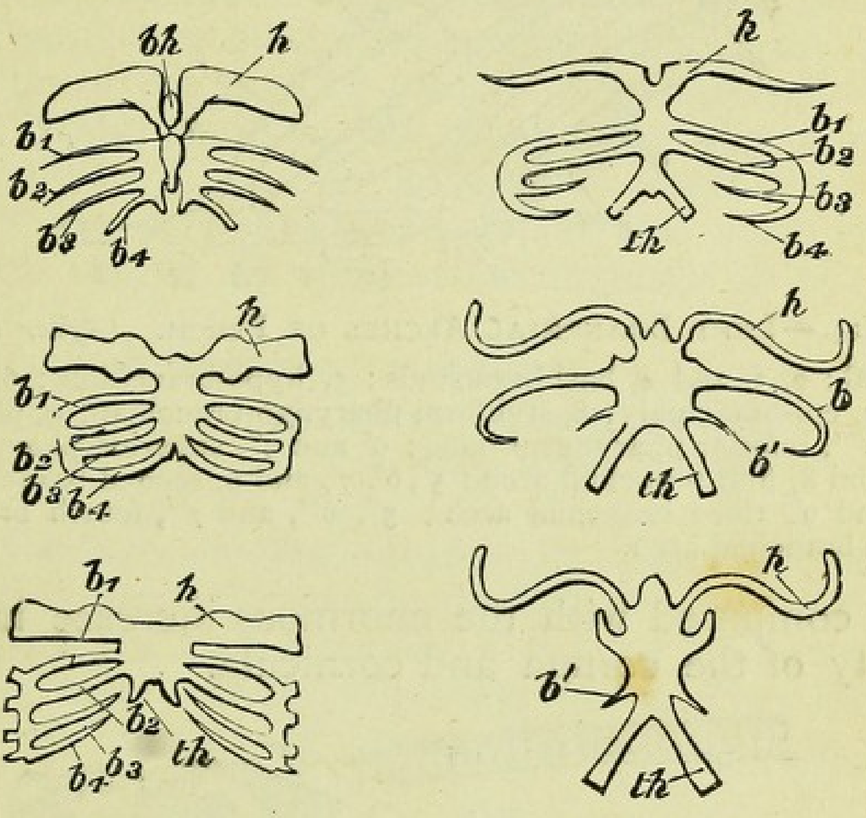

FIG. 113.—Diagram of the Changes undergone by the Hyoid in a Frog in passing from the Tadpole stage to the adult condition.

(*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.

The cornicula represent only the so-called hyoidean arch—namely, that arch in Fishes which comes behind the lower jaw and in front of the branchial arches.

We have seen that in man's own class this arch may consist of several distinct bones, that is to say, of a tympano-hyal, a stylo-hyal, an epi-hyal, and a cerato-hyal, though in man himself the epi-hyal is only represented by ligament. It is, therefore, less surprising that in the lowest vertebrate class this arch should be large and complex with bony appendages (termed *branchiostegal rays*) diverging from the large cerato-hyals.

The body of the hyoid is small in Fishes, and excessively

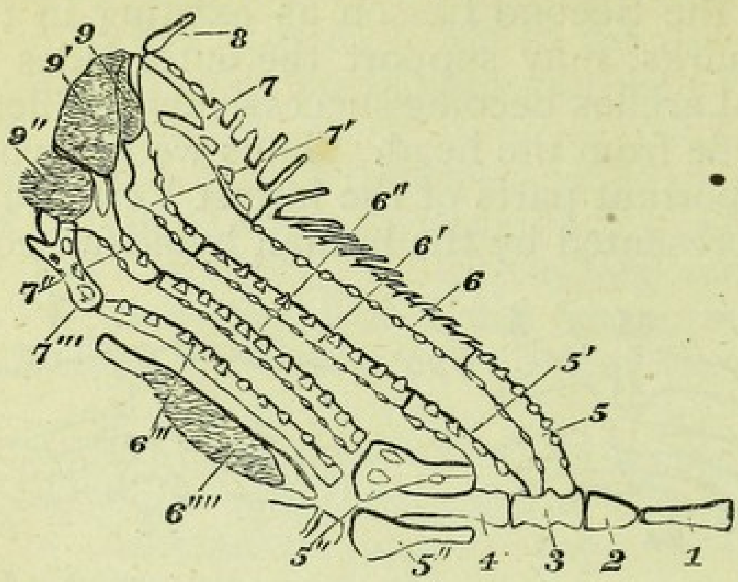

FIG. 114.—LEFT BRANCHIAL ARCHES OF PERCH. (*After Cuvier.*)

1, glosso-hyal; 2, 3, and 4, basi-branchials; 5, hypo-branchials; 6, cerato-branchials; 7, epi-branchials; 8, styliform pharyngo-branchial; 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.

so when compared with the enormous increase in size and complexity of the cornua and cornicula.

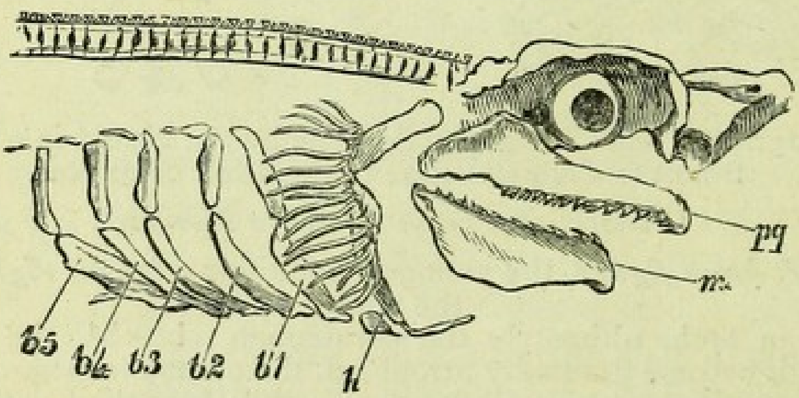

FIG. 115.—SIDE VIEW OF THE CARTILAGINOUS SKELETON OF THE HEAD OF A SHARK.

This shows the successive arches except the first pair, or *trabeculæ cranii*, which form the base of the skull in front of the pituitary fossa.

pq, pterygo-palatine, or second arch; *m*, mandibular, or third arch; *h*, hyoidean, or fourth arch (the corniculum, stylo-hyoid ligament, styloid process, &c., of man). From behind it the branchiostegal rays are seen extending backwards. 6^1 to 6^5, the branchial arches forming the fifth, sixth, seventh, eighth, and ninth arches of the skull.

(*From the College of Surgeons' Museum.*)

A glosso-hyal and a uro-hyal, however, may exist, as we see in the Cod.

33. Those CONNEXIONS OF THE BONES of the skull one with another which take place in man are not all constant in Vertebrates generally, as we have already seen. Certain unions, however, are absolutely constant and invariable, as that of the basi-occipital and basi-sphenoid—the pre-sphenoid and basi-sphenoid—the parietal and occipital—the maxillary and jugal, when the last-mentioned bone is present.

Several exceptional connexions have been already given.

In the skull of many Vertebrates vacuities often exist where bone is present in man—tracts osseous in him being represented by membrane only. An example of such defect is seen in that region of the skull of Lizards (*e.g.* Iguana) which corresponds with the wings of the sphenoid of the human skull.

The transitory fontanelle[1] of man is permanent in some animals, as *e.g.* certain Sharks, where the cranium is to a large extent roofed by membrane instead of by bone or cartilage.

The excessively dentated condition of certain sutures in man is exceptional, nevertheless not unparalleled. We may sometimes (*e.g.* in the Gorilla) find sutures even more complex.

The persistence of the sutures in man is less than in many animals, and also greater than in many. Thus we may find, as in Fishes and Reptiles, a variety of bones distinct which in him are united. We may, on the other hand, as in Birds, find a number of bones united which in him are distinct.

One suture, however, which, as has been mentioned, almost constantly persists in other forms than man, is not represented in him (except on the palate), even at birth. This is the one between the maxilla and the pre-maxilla. Again, the intimate union which exists in him between the basi-sphenoid and the pre-sphenoid is very far from persisting even in his own class.

On the other hand, that distinctness which always obtains in him between the petrous part of the temporal bone and the occipital portion of the skull, is very early lost in the Sauropsida.

The skull may present a much less compact mass than in man's class.

Thus in Birds the elongated facial bones which go to form

[1] The fontanelle is a space on the crown of the head, which, in the new-born infant, is only closed by fibrous structures, the parietals and frontals not having yet joined.

the upper beak, being thin and elastic, are more or less movable on the rest of the skull, and in the Parrots even by a joint. In Lizards the anterior part of the skull is also more or less movable on the posterior part. In Fishes we meet with an extreme mobility of the jaws (the mandible being suspended by a chain of bones), as also in Serpents, in which not only is each side of the lower jaw separately movable and united at the symphysis by a very elastic ligament, but each part of the upper jaw can also be advanced singly; and thus, by successively advancing one tooth-bearing part of the jaw after another, these animals rather drag themselves over their prey than swallow it.

34. The general conformation of the skull shows that almost always the proportion borne by the jaws to the cranium is greater than in man; and often, as in the Stork, the Whale, the Gavial, or the Sword-fish, it is the facial part which is enormously predominant. Thus the skull may be extraordinarily elongated as compared with that of man, and tapering anteriorly, or it may be much broader in front than behind, as in the Hammer-headed Shark. It may also be very elongated but cylindrical, as in *Centetes.* It may be strangely flattened, as in the Matamata Tortoise (*Chelys*), or it may be singularly compressed from side to side, and high, as in the fish *Argeriosus.*

Considering now the EXTERNAL SURFACE of the skull, the *superior region* of man's is very exceptional in its extent, its smoothness, and its rotundity. Generally in man's own class a prominent sagittal ridge runs from in front backwards in the line of the sagittal suture. This may be enormous, as in some Seals and Carnivora, and even in the very Anthropoid Gorilla. One of the most exceptional conditions which this region may present is that exhibited by the Sperm Whale, or Cachalot, where the cranium forms above, a great semicircular basin for holding the spermaceti. In this and certain other animals of the same order there is a want of symmetry in the skull when looked at from above; the two nostrils and pre-maxillæ being more or less unequally developed. This asymmetry is carried much further in some of the true Fishes (namely, the *Pluronectidæ*, e.g. the Sole, Turbot, Flounder, &c.), where the anterior part of the skull is extraordinarily twisted so as to allow both the eyes to come to be on one side of the head.

Generally when the upper surface of the skull is looked at, the anterior nares are more or less inconspicuous, and placed in front. In certain animals, however, as the Elephant, the

Sirenia, and the Cetacea, they look upwards, and open quite on the superior aspect of the skull. The same may be said of those animals with a short proboscis, the Tapirs and the Saiga Antelope.

The occiput may slope so forward that much more of it may be seen (when the skull is viewed from above) than in man, as is the case, *e.g.*, in the Cape Mole (*Chrysochloris*), the Elephant, and the Porpoise. It may, on the contrary, be hidden by the projection of a large lambdoidal crest, as in the Gorilla and Hyæna.

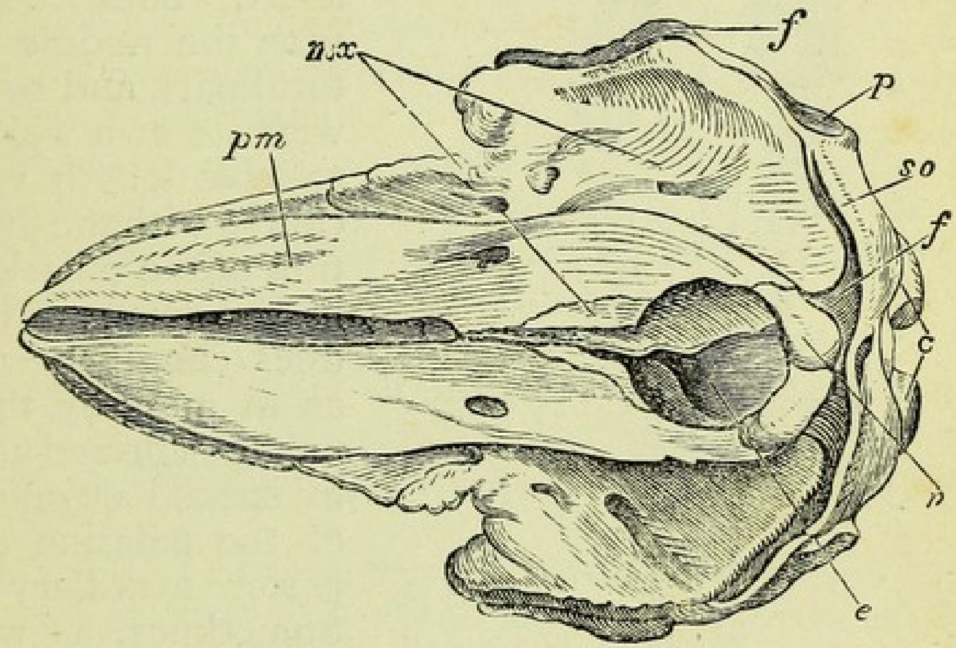

FIG. 115.—UPPER VIEW OF THE SKULL OF A DOLPHIN (*Delphinus globiceps*). (*After Cuvier*)

c, occipital condyles ; *e*, median ethmoid in nasal fossæ ; *f*, frontal, overlapped by *mx*, maxilla : *n*, nasal ; *p*, parietal, driven down quite to the side of the skull ; *pm*, pre-maxilla (here enormous) ; *so*, supra-occipital.

It is possible that this region may be in large part membranous, as in some Rays.

On the contrary, great bony productions may exist, as in Ruminants ; either permanent bony cores sheathed with horn as in the Ox, Goat, &c., or else bony developments (antlers) which are annual in their growth and decay.

There may be four bony cores, as in the existing little four-horned Antelope and in the great extinct *Sivatherium*.

The roof of the cranium may falsely appear to be large and smooth, as in the Turtle and in the Rodent *Lophiomys*. In them the real skull is disguised by the outgrowth of bony lamellæ, which, meeting together, arch over the temporal fossæ, and make the skull look capacious when it is not really so.

The *inferior region* is very rarely divisible into the three

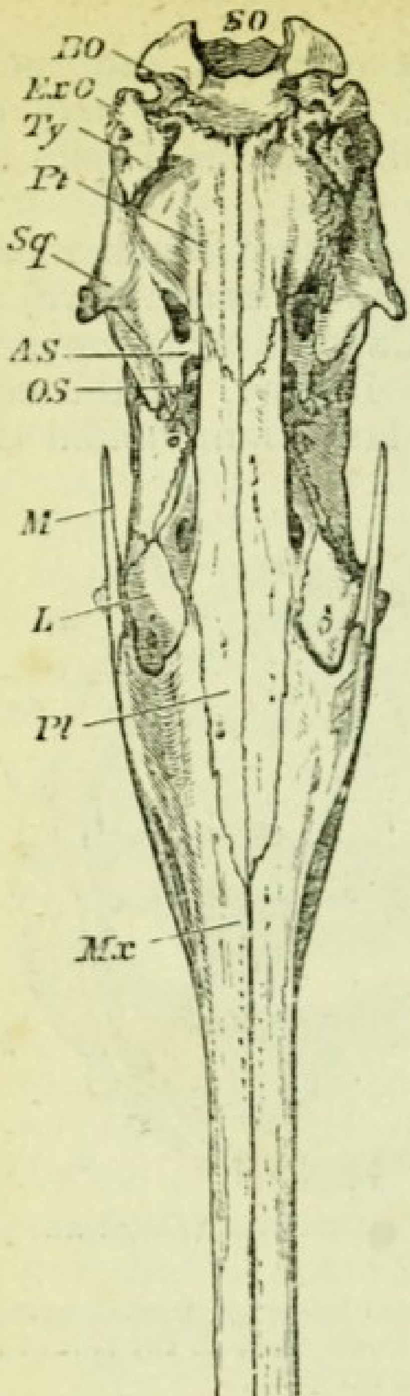

FIG. 117.—Under Surface of the Cranium of the Great Ant-eater (*Myrmecophaga jubata*), ⅓. *SO*, supra-occipital; *BO*, basi-occipital; *ExO*, exoccipital; *Ty*, tympanic; *Pt*, pterygoid; *Sq*, squamosal; *AS*, ali-sphenoid; *OS*, orbito-sphenoid; *M*, malar; *L*, lachrymal; *Pl*, palatine; *Mx*, maxilla; *PMx*, pre-maxilla.
(*From Flower's "Osteology."*)

parts of which it is made up in man, the anterior margin of the occipital foramen forming, in the immense majority, part of the posterior boundary of the inferior region.

(1) The anterior part of the basis cranii of man is in him very exceptionally short, both compared with the middle or guttural part, and compared with its own width. Its relative length varies of course with the prolongation of the muzzle. Only in Mammals and Crocodiles can it be defined, as in man, by the bony palate—formed as in him by special developments of the palatine and superior maxillary bones. Sometimes, as we have seen, this part may be augmented by the pterygoid bones also taking a share in this structure, as in the Great Ant-eater, the Crocodiles, and Cetaceans.

It is possible, however, as in the Hare, for the bony palate to be very little developed, or, as in the Hedgehog, to be only imperfectly ossified. The form and proportion of its component bones afford in Birds important characters for the classification of different groups.

Essentially palatal structures, namely the pterygoid bones, n forms below the mammalian class, generally connect the palatine bones with the quadrate bone which suspends the ower jaw. The bony palate may be enriched by the addition of a bone not known in Mammals (the *os transversum*), as is he case in Reptiles; or of two extra bones (the ecto-pterygoid and the ento-pterygoid); besides a third peculiar ossification the meta-pterygoid), as in bony Fishes.

(2) The middle, or guttural part, is a noteworthy one, both on account of the physiological importance of the structures which modify its composition, and also on account of the ralue which its various modifications possess for the purposes of zoological classification.

Its condition in man is exceptional, both as regards the arge proportion it bears to the anterior part of the basis ranii, and also as regards its small elongation antero-posteriorly as compared with its breadth.

The variations presented as regards the mastoid and styloid processes, the carotid foramina, alisphenoidal canals (for he external carotid arteries), &c., have been already noticed n speaking of the separate cranial bones, and need not here e repeated.

Sometimes, as in the Crocodile and Great Ant-eater, this uttural part of the basis cranii is nearly concealed by the nmense extension of the palate. At other times, as in the Horse, it is much exposed by the smallness of the backward rolongation of the bony palate.

The pterygoid fossæ are found only in man's class, and by o means always in it. Generally, as in the Dog, the pterygoid ones are present, but the descending external pterygoid rocess is absent; so that the pterygoid fossæ want seemingly heir outer walls.

The pterygoids may be swollen out into bullate expansions, s in the Mole and Sloths.

Very often, especially in the smaller Mammals, the part nswering more or less to the petrous part of the temporal nd to the meatus auditorius externus may be, as it were, lown up into vesicular air-containing prominences, termed uditory bullæ.

The Eustachian tubes may unite to open into the mouth y a median foramen, as in Birds, or may be utterly absent, s in Fishes.

(3) The posterior part of the inferior region of man's skull very exceptionally developed, owing to the advanced situa-

tion of the foramen magnum. Nevertheless, its maximum of development in Mammals is not found in him, but in the little American Ape *Chrysothrix*.

In the great majority of instances the occiput is not visible when the skull is looked at from beneath, or a projecting lambdoidal ridge is seen in the place of the lambdoidal suture. Occasionally, however (as in the Woodcock), the occipital surface is largely visible, the foramen magnum being situated far forwards.

A peculiar character may exist in the occiput, as can be seen in the Indian Elephant, where there is a deep and sharp double depression with a median, vertical ridge. This depression curiously resembles that in which the cribriform plate is placed in so many Mammals, the median ridge reminding one of the crista galli. This occipital fossa is for the reception of a strong ligament, which helps to sustain the very weighty skull.

An anterior condyloid foramen may be entirely absent, as in Fishes, in which class there is no distinct hypoglossal nerve.

Great depending para-mastoid (or par-occipital) processes may replace the mastoids, as in the Horse and the Capybara.

The *anterior region* of the skull of adult man presents an appearance but very rarely approached by that of any brute. Nevertheless, certain of the American Monkeys (e.g. *Pithecia* and *Nyctipithecus*) present a close general resemblance, which is also to be plainly seen in the young Chimpanzee, and still better in the young Orang Utan.

Generally speaking, owing to the prolongation of the muzzle, the skull is so much foreshortened when viewed in front that its actual shape can be very little seen. The same apparent distortion also occurs in extremely depressed or compressed skulls.

Although the rounded frontal region of man is all but peculiar to him, his superciliary projections are but rudiments of what may be developed even in closely allied forms, as we see in the Gorilla, the superciliary ridges of which are enormous. Very generally the orbital fossæ are placed so laterally that, unlike those of man, they are very little seen when the skull is looked at in front. On the other hand, they may approximate more closely than in him, as in many Monkeys. As has been said in describing the superior maxillary bone, the infra-orbital foramen may be replaced by a great aperture, or by a number of small apertures. The bony cheek may, in man's own class, offer defects of ossification, as in the Hare, or enormous prominences enclosing a chamber, as in the Paca, or great swollen tuberosities, as in the Mandrill.

The anterior nares may be so high up as to approach the summit of the skull, as we see in Cetacea. They may present a very large aperture, as in the Tapir. They may be widely separated one from the other in the middle line, as is the case in most animals below Mammals, but not in all, as we see in Chelonians and Crocodiles, which have a median, single nasal opening, as in man's own class.

As regards the lateral regions of the skull of man :—

(1) The *temporal* part may be roofed over and hidden from view by plate-like processes extending out from the adjacent bones, and which, meeting, enclose the temporal fossa and muscle, giving the skull a fictitious appearance of great capacity. This is the case in the Turtle, the African Rodent *Lophiomys*, and in the Frog *Pelobates*.

(2) The *mastoid* part can hardly with propriety be so called in lower forms, where the mastoid process becomes much smaller or aborts altogether.

The meatus auditorius externus may in the adults of very high animals (*e.g.* the American Apes) be replaced by a wide, nearly circular opening, as in the human skull at birth. The same meatus may be directed much upwards and more or less backwards, as in the Hare. No such part exists in the skulls of Fishes.

(3) The zygomatic part may in man's own class present very considerable differences from the structure which exists in him, and more considerable still in lower forms.

Thus a zygomatic arch may be wanting, as in *Centetes*, the Ant-eaters, and *Manis*. Both the anterior and posterior parts of that arch may be well developed, and nevertheless may fail to effect a junction, as is the case in the Sloths and their extinct allies; or a junction may be formed by the help of a process of the frontal, as in the Horse.

In forms below Mammalia (as *e.g.* in Birds, the Crocodile, &c.) we often find a zygoma formed by the help of a bone termed the *quadrato-jugal*, which connects the malar in front of it with that bone which supports the lower jaw, and which is termed the quadrate. Besides this zygomatic arch a second and superior zygoma may exist (as in most Lizards and in some Birds, *e.g.* the Macaw "*Calyptorhynchus*"), formed by the union of the squamous or zygomatic element of the temporal bone with a bone termed the post-frontal, and which more or less occupies the place of the post-frontal process of the frontal bone of Mammals.

A fundamentally different structure may obtain, as in Fishes, where we have, as a rule, no malar; and where the more conspicuous representative of the temporal bone (exclusive of the representatives of the petrous portion) is the pre-operculum, —which may perhaps be said to replace a zygoma, extending down as it does to the quadrate bone which suspends the lower jaw. The connexion of the quadrate bone, however, with the maxillary bone is only effected by means of soft structures, which must alone, therefore, represent the inferior zygoma of the Sauropsida. The bones which connect the quadrate with the upper jaw have relation not to the zygoma, but to the palate.

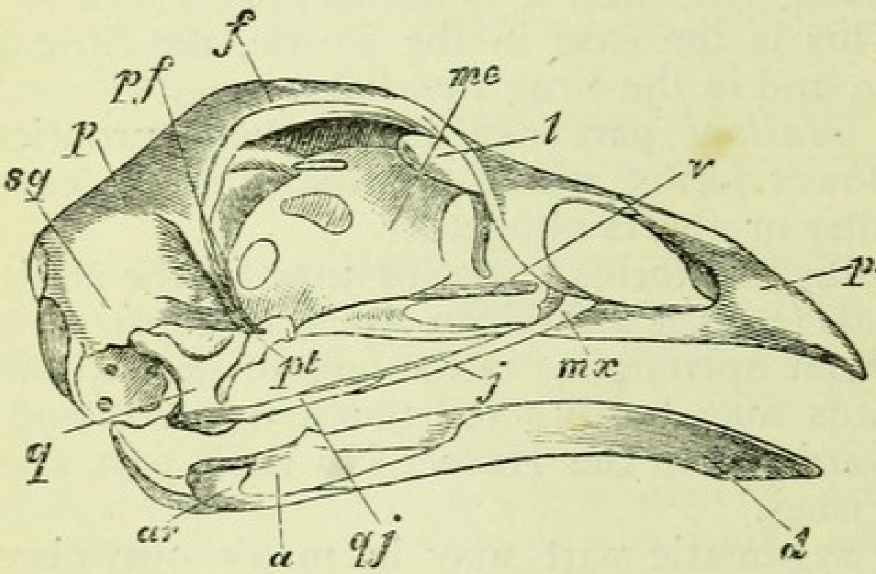

FIG. 118.—SIDE VIEW OF A BIRD'S SKULL. (*After Parker.*)

a, surangular bone of mandible; *ar*, articular bone; *d*, dentary; *f*, frontal; *j*, malar; *l*, lachrymal; *me*, median ethmoid; *mx*, maxillary bone; *p*, parietal; *pf*, post-frontal process; *pt*, pterygoid bone; *px*, pre-maxilla; *q*, quadrate bone; *qj*, quadrato-jugal; *sq*, squamosal; *v*, vomer.

Returning to man's own class, we find that the lateral region is generally much more open than in him. The spheno-maxillary fissure, for example, is defined by the projection outwards of the alisphenoid. Generally this projection is wanting; therefore the orbit opens widely into the temporal fossa. This fissure may, however, be more closed up than it is even in man, as we see in certain Apes, and notably in the Howling Monkeys.

The pterygo-maxillary fissure may also become as it were more or less opened out, and the spheno-maxillary fossa be plainly visible, instead of being hidden, as it is in man. The five foramina of that fossa, viz. the rotundum, vidian, pterygo-palatine, posterior palatine, and spheno-palatine, are generally present in the Mammalian class, but with the opening out of the fossa become more or less, and in different degrees, separated from each other as compared with their common juxtaposition in man. The spheno-palatine and posterior palatine foramina may together be represented by a single small opening, as in the Ornithorhynchus.

35. Before considering the INTERNAL SURFACE of the cranium as treated of in Anthropotomy, it may be well to note the relations and conditions presented by a vertical longitudinal section of the entire skull, which are exceedingly significant and instructive.

The basi-cranial axis of man forms an angle which approximates to a right angle with the basi-facial axis.

In Birds the angle may be as marked as in man, and the human condition may be even much surpassed, as in the Woodcock, where the facial part is so extremely bent down that its axis forms a very acute angle with the basi-cranial axis.

Now, in all the lowest Vertebrates these two axes are in one straight line, as in Fishes, Batrachians, and most Reptiles; and even in most Mammals the angle formed by them is an exceedingly open one, approximating to 180°.

The importance, however, of this distinction is not really so great as at first appears, for there are great differences with regard to it between animals which are very nearly allied. Thus the adult Chacma Baboon differs from his ally the Mandrill in this respect almost as much as man differs from the Gorilla; and while the Deer has the two axes almost on a line, in the Sheep and Ox they form a very marked angle.

The shortness of the basi-cranial axis in man when compared with the extreme length of the true brain cavity, is a much more distinctive feature, as in all lower forms this axis is very much longer. Thus, in the Sheep, the basi-cranial axis is as long as the entire cerebral cavity, and in the lowest Vertebrates (where the cerebral hemispheres form but a small part of the brain) it very greatly exceeds it.

Similarly the angle formed by it with the plane of the occipital foramen, which is so very open in man, contracts in lower Vertebrates till it becomes a right angle; and the same may be said as to the olfactory angle, or that formed with the basi-cranial axis by the plane of the cribriform plate, or its morphological equivalent.

In this way the peculiarly expanded condition of the cerebral chamber of man may be appreciated. Taking the basi-cranial axis as a fixed line for comparison with other animals, we see that in him (Fig. 91) the cerebral chamber is of great vertical extent, at the same time that its anterior portion is so expanded as to open out the olfactory angle from 90° to much beyond 180°, and to similarly open out the occipital angle—circumstances in which man widely differs from even the highest members of his class and even of his order.

In the fact that the inside of the *arch* of the skull is marked by depressions corresponding with the cerebral convolutions,[1] man agrees with those members of his class which possess such convolutions. For in that class the cranium closely invests the brain, so that a cast of its cavity well exhibits the general features of the cerebral surface. This character, however, is by no means universal in the Vertebrates, for the cerebral cavity does not contract with the lessening proportions of the cranial nervous centres, there being (*e.g.* in Fishes) a large quantity of soft fatty substance interposed between those centres and the cranial walls.

The cranial cavity in man overhangs the orbits, but does not descend between them. This is a condition which obtains very often, but by no means universally; for that cavity may be not only prolonged between the orbits, but considerably beyond them. We find this in Serpents, in Batrachians, and in many Fishes (*e.g.* the Carp family), while in Birds, Lizards, Crocodiles, and Chelonians the cranial cavity suddenly contracts, and there is an interorbital septum only.

The middle of the dome of the skull may be produced inwards as a median, longitudinal, bony plate by ossification of the falx. This is the case *e.g.* in the Ornithorhynchus and in the Sea Lion.

An ossified tentorium may exist, as in some Spider Monkeys, in the Racoon, and others.

The *base* of the interior of the skull may present those differences already noticed in describing the several cranial bones. In man's class it is divisible into the same three fossæ as in him. This division, however, is not similarly marked in lower forms.

(1) The *anterior fossa* is relatively much less extensive in man than it is in most animals. Even in the Apes the

[1] For these see Lesson VIII.

portion immediately above the cribriform plate forms a more distinct chamber than exists in man. As we descend through the mammalian class we often find it much prolonged and of a large relative size, as in the Sheep, Pig, and others, especially Marsupials, *e.g.* the Thylacine. In some forms, however, *e.g.* the Dolphins, the olfactory fossa is quite wanting. Great difference in this respect may exist in nearly allied forms—*e.g.* in the Ornithorhynchus and Echidna, in the first of which the cribriform plate is very small and bird-like, while in the second it is enormously large.

(2) The *middle fossa* is relatively larger in man than it is in very many lower forms, but not in all, as we see by the Dolphins. The foramina vary, as already noticed in describing the several cranial bones. Very often the foramen rotundum and sphenoidal fissure may be blended in a single opening, as in the Squirrel; or the optic foramen may form but one aperture with the sphenoidal fissure, as in the Stag and Opossum; or the two optic foramina may be united into a single median foramen, as in the Hare.

The foramen ovale may be one with the foramen lacerum anterius, as in the Horse.

The optic foramina and sphenoidal fissures may together be represented, on the inside of the skull, by a single opening, as in the Swan; and sometimes the optic foramen, sphenoidal fissure, and foramen rotundum may be included in a common aperture, as in the Booby.

The sella turcica may be as sharply limited in other forms as in man. On the other hand, the pituitary fossa may be altogether unmarked, as in Batrachians.

This fossa may dip down into a large canal running forwards and excavated in the basis cranii, as in many Fishes, *e.g.* the Pike. This singular cavity has the cartilaginous floor of the skull for its roof, while the para-sphenoid bone encloses it below.

(3) The *posterior fossa* may be much more sharply defined than in man, as when a lamella of bone (consisting of an ossified tentorium) is attached to the projecting border of the petrous part of the temporal bone. The proportion borne by this fossa to the middle one varies with the size and development of the cerebellum which it shelters. Only in man and a few Apes (notably the Squirrel Monkey, *Chrysothrix*) can this fossa be said to form any considerable part of the floor of the skull. The internal auditory foramen in all man's class and in Birds is placed as in him, and there

is generally (as notably, *e.g.*, in the Hare and Mole) also a fossa for that process of the brain called the flocculus of the cerebellum.

In some Reptiles, however (as, *e.g.*, the Turtle), the bony investment of the internal ear is incomplete on its cranial side; and in Fishes it is even widely open, forming a large chamber communicating with the general cranial cavity, and termed the "otocrane."

36. That degree of completeness of THE ORBITS which exists in man—serving for the protection of the eyeball by extensions of the cranial bones—is a very exceptional condition. Only in him and in the higher members of his order—that is, the Monkeys—do we find such an enclosure; but in some of them it may be more complete than it is in him, by the junction of the greater wing of the sphenoid with the upper maxillary bone, so that the spheno-maxillary fissure is reduced to a short and rounded aperture, or even (as in the Howling Monkeys) all but or quite obliterated.

The relative size of the orbits may be much greater than in man, as *e.g.* in *Indris*, in the Night-Ape (*Nyctipithecus*), or in the Tarsier. On the other hand, the orbits may be relatively smaller than in man, as in the Whales.

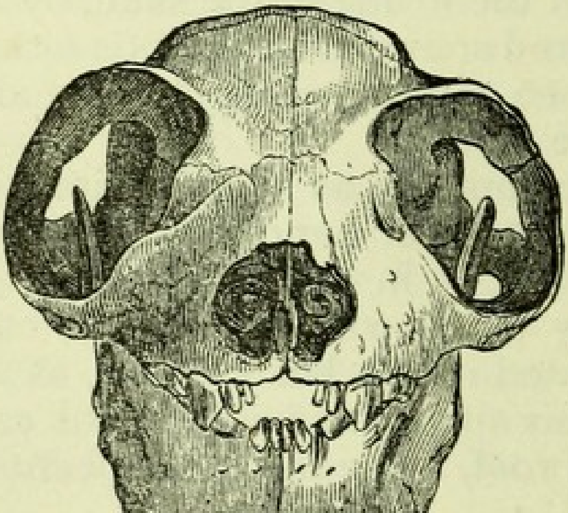

FIG. 119.—Front View of the Skull of the Lemuroid *Indris Laniger;* showing the large size of the orbits, which are also shown to open widely behind into the temporal fossæ.

They may be much more widely separated from each other in proportion to their size and the size of the skull, as in the Dog and most Mammals. On the other hand, they may be much more approximated, as in the Tarsier and in the Squirrel Monkey (*Chrysothrix*), where they are in part separated by membrane only. In a great number of animals, as Birds and many Reptiles, they are only divided from each other by a thin interorbital septum, made up of bone or cartilage or membrane. They may, on the contrary, be so widely separated (as in the Hammer-headed Shark) that the cranium is much broader between them than it is anywhere else.

Although it is peculiar to man's order to have the orbit enclosed as in him, yet there are other creatures which have the orbit protected by a bony rim, as is the case in Ruminants (*e.g.* the Sheep), in the Crocodiles and Turtles, some Lizards, and some Frogs. This enclosure is effected by the junction of the malar with the true frontal bone (in Mammals, except in the Horse, where the zygomatic process of the temporal bone intervenes) or with a post-frontal bone. In many fishes, however, the orbit is bounded inferiorly by a chain of skinbones (dermal ossicles), the suborbital bones, which seem to be serial repetitions of the lachrymal; and in some Birds (*e.g.* the Woodcock and the Macaw, *Calyptorhyncus*) there is an analogous formation, and the orbits are completely encircled by bone.

In the immense majority of man's class, however, the orbit is not even encircled by bone, and its separation from the temporal fossa is not in many even marked by a post-orbital process of the frontal. The lachrymal foramen (which exists in most terrestrial forms) need not open within the orbit, but may be, as in Lemurs, upon the cheek.

The orbits may be continued backwards (as in many osseous Fishes, *e.g.* the Pike) into a prolonged conical canal situate beneath the cerebral cavity, and protected inferiorly by the para-sphenoid.

In the possession of *nasal fossæ* limited and defined by osseous structures man agrees with the whole of the Vertebrata above Fishes, except the very lowest of the Batrachians.

In the possession of two such fossæ separated by a wide or narrow septum, and separated from the mouth by an osseous plate, so that they open posteriorly only into the pharynx,[1] man agrees with all the members of his class, and with the Crocodiles also.

The sheltering of spongy bones (or turbinals) is a character which the nasal fossæ possess in almost all Mammals, though such parts may be entirely wanting, as in the Dolphins. These spongy bones may be represented only by cartilaginous structures, as we find in the classes Reptilia and Batrachia.

[1] For the pharynx see Lesson XI.

The floor of these fossæ may, instead of forming with the basi-cranial axis an angle opening downwards (as in man, the Hare, and Sheep), be parallel with it (as in the Dog), or form an obtuse angle opening upwards, as in the Elephant, or even a slightly acute angle, as in the Dolphins.

The nares are exceptionally high in proportion to their length in man. Their length may be enormous, as in the Great Ant-eater and Crocodile, where pterygoid plates follow behind the palatine bones and so prolong the bony palate.

The nares, on the contrary, are in most Vertebrates much shorter than in Mammals; for there are no palatal plates to prolong the fossæ backwards, and their *posterior* border is formed by the palate bones. Thus the posterior nares in such animals (*e.g.* Birds, Lizards, Frogs) answer rather to the middle portion of the human nasal fossæ.

The bones which form the anterior and posterior boundaries of the nasal passage have been already described, as also the asymmetrical form of the anterior nares in the Cetacea.

The median division of the fossæ, or septum narium, need not be partly osseous and partly cartilaginous, as it is in man. It may be quite unossified, as in Chelonians and Serpents, or it may be ossified to the ends of the nasals, as in certain extinct species of Rhinoceros and in some Dolphins and Seals (*e.g.* the species *Leonina*), and in one species of Tapir, where ossification advances even in front of the nasals. The septum may be ossified continuously with the lesser wings of the sphenoid, as in the Frog, where it forms the middle part of the *os en ceinture*.

As to the *frontal*, *sphenoidal*, *and maxillary sinuses*, it is a general character of air-breathing Vertebrates to have some or other part of the cranial bones furnished with cavities containing air. In this respect, therefore, man is no exception to the rule, and indeed he occupies an intermediate position, as cranial air-cells may be more restricted or much more developed than they are in him, and this not only as regards the relative size of the air-cavities, but also as regards the number of cranial bones so inflated.

The *frontal sinuses* (which are not constant in man, being absent at least in some Australian skulls) may be much less or more developed than in him in members of his own order, *e.g.* in different Apes. In hollow-horned Ruminants they may extend into the substance of the horns, or backwards into the parietals and supra-occipital. The latter condition exists in the Hog, but attains its maximum of development in the Elephant, where air-cavities extend even into the nasal bones; and the vertical section of the area of the cranial sinuses exceeds, in the adult, that of the cranial cavity itself.

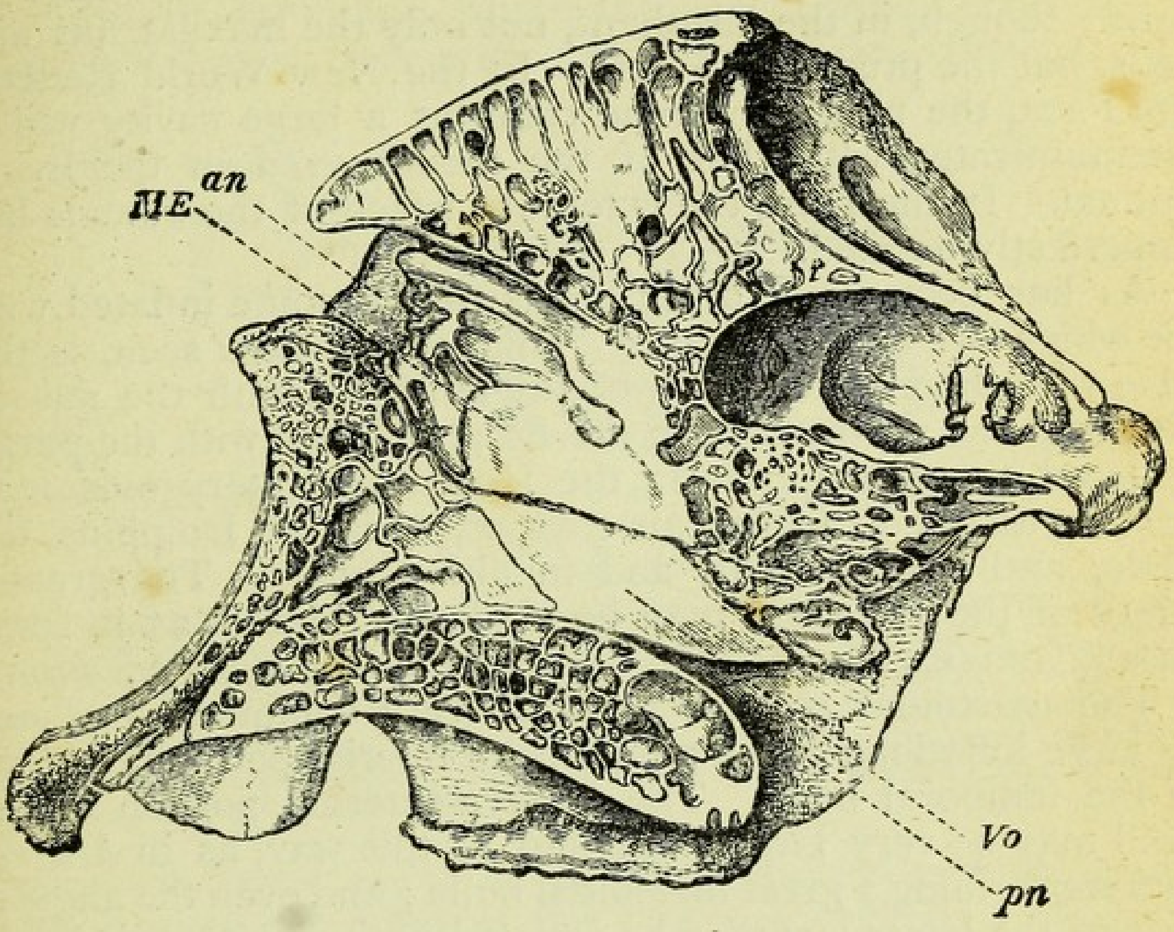

FIG. 120.—A section of the Cranium of a full-grown African Elephant, taken to the left of a middle line, and including the vomer (*Vo*), and the mesethmoid (*ME*): *an*, anterior, and *pn*, posterior narial aperture, $\frac{1}{12}$.

This section shows the enormous thickness of the skull wall, and the prodigious development of air-cells in the frontal above and in front of the cerebral cavity, and above and behind the anterior nares, *an*.

(*From Flower's "Osteology."*)

In Birds also they may be well developed, while, on the contrary, an extraordinarily dense projection of bone may take place from the frontals, as in the Cassowary. Frontal sinuses may be entirely wanting, as in many Mammals and Reptiles, and as in the Frog, and this though other cranial elements have large air-cavities, as in the Crocodile.

The *sphenoidal sinuses* may be much less developed than in man, as is the case in common Monkeys and many Mammals, *e.g.* the Sheep and Manatee. They may, however, be very greatly developed and extend into the median plate of the ethmoid, as in the Elephant. Similarly, in oviparous

Vertebrates, they may be largely developed, as in many Birds, *e.g.* the Ostrich; or absent, as in Serpents, *e.g.* the Python.

The *maxillary sinus* in man is also in a medium state of development. In very many forms the maxillary bone is solid; though, in the Elephant, not only the maxilla has air-cells, but the pre-maxilla also. In the New World Rodent, the Paca, the maxillary bone contains a large cavity which communicates with that of the mouth even in the living animal. In the Hare the external surface of the bone is but imperfectly ossified.

As has been said, other bones may become inflated with air which are not so in man. This, as we have seen, is the case with the median plate of the ethmoid, with the nasals, and with the pre-maxilla in the Elephant, and with the parietals and supra-occipitals in the Hog. The pterygoids may become adapted to form air-cavities, as in the Dolphins, the Mole, and some Sloths, and in old Gavials. The greater wings of the sphenoid may be similarly dilated, as in some Insectivora (e.g. *Centetes*) and Marsupials (e.g. *Hypsiprymnus*).

The mastoidal cells of man are very commonly replaced by large inflations of the tympanic or inferior petrous portions of the temporal bone. The postero-external portion of the skull may be very largely inflated in this way, as in *Macroscelides*, forming a great mastoidal bulla; and even the angular part of the lower jaw may be inflated with air, its cells being placed in communication with those of the tympanic region by a special tube, as in the Crocodile.

The lachrymal bone may also be inflated and form an orbital bulla, as in almost all Ruminants, especially the Giraffe.

The upper jawbones may be extraordinarily expanded and filled with delicate osseous air-holding cells, as in the beak of the Toucan.

The process of DEVELOPMENT of the human skull, which has been before noticed, is of very high zootomical interest, as its transitory stages present very interesting resemblances to the permanent cranial structures of very different animals.

Inasmuch as we find in the first indication of the embryo an indication of the spinal system which is to be, but none of the skull, we are reminded of the headless condition of that lowest of Vertebrates, the Amphioxus or Lancelet.

In that early cartilaginous condition of the cranium in which we have a cartilaginous mass enclosing the anterior termination of the notochord in the middle, and an auditory capsule on each side of it, we are reminded of the permanent condition of the skull in the Lamprey.

In that the trabeculæ cranii first diverge and then converge, meet, and so enclose what becomes the pituitary space, we find a temporary condition of which large traces remain even in adult Ophidians, where the cartilaginous trabeculæ persist as two rods, one on each side of the para-sphenoid.

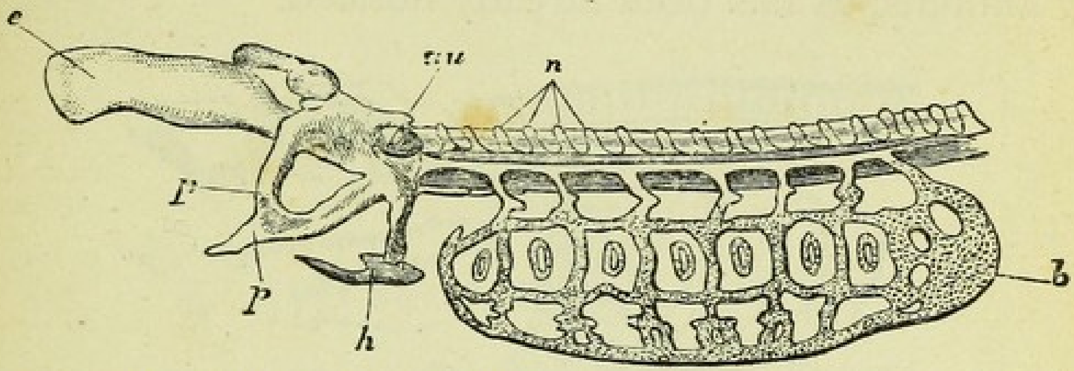

FIG. 121.—THE SKULL, ANTERIOR PART OF SPINAL COLUMN, AND BRANCHIAL BASKET OF THE LAMPREY.

(*From Müller and Owen.*)

au, auditory capsule; *b*, cartilaginous basket, connected above with the side of the vertebral column, with seven complete and descending arches united by transverse bands (between which the gill-openings are seen) and sheltering the heart and pericardium at the part where the letter *b* is placed; *e*, ethmo-vomerine cartilage; *h*, rudiment of the hyoid; *n*, neural arches; *P*, palato-quadrate (or pterygo-palatine) arch, the hinder pier of which represents the suspensorium, though there is no lower jaw.

Before the development of the third visceral arch we have the permanent condition of the Lamprey, which is always destitute of a mandible; and when, in man, the visceral arches successively arise, we have transitorily represented the piscine condition, where the solid axes of seven or more such arches form the mandible, the hyoidean arch, and the successive branchial or gill-bearing arches.

In the development of the palatal, or second visceral arch, there is sketched out a condition permanent in Sharks, where the lower jaws bite against a cartilaginous pterygo-palatine arcade which takes the place of an as yet undeveloped bony upper jaw. This condition is essentially similar to the structure of the Sturgeon, where a comparatively minute pair of jaws (mandibular and pterygo-palatine respectively) are suspended at the end of a disproportionately large suspensorial structure.

In that stage of the human skull which precedes ossification we have a reminder of the exclusively cartilaginous structure of certain Fishes.

In the distinct ossific origin of the elements of the petrous and mastoidal portions of the temporal bone we have a transitory representation of the permanent conditions of the same parts in the osseous Fishes.

In the distinct osseous origins of the wings of the sphenoid, of the basi-occipital and basi-sphenoid, and of the lateral parts of the occipital bone, there is exhibited a resemblance to the permanent condition of those parts as they exist in many animals, as has been already noticed.

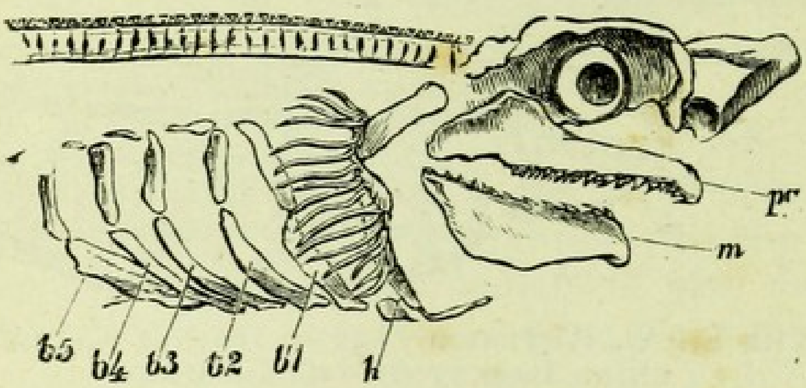

FIG. 122.—SIDE VIEW OF THE CARTILAGINOUS SKELETON OF THE HEAD OF A SHARK.

This shows the successive arches except the first pair, or *trabeculæ cranii*, which form the base of the skull in front of the pituitary fossa.

pq, pterygo-palatine, or second arch; *m*, mandibular, or third arch; *h*, hyoidean, or fourth arch (the corniculum, stylo-hyoid ligament, styloid process, &c. of man) From behind it the branchiostegal rays are seen extending backwards, 6^1 to 6^5, the branchial arches forming the fifth, sixth, seventh, eighth, and ninth arches of the skull.

The same remark applies to the other parts which, at first distinct, ultimately coalesce, such as the portions of the ethmoid, the upper maxillary bones, the pterygoid processes, and the squamous element of the temporal bone.

Finally, that exceptional anchylosis which occasionally takes place in aged skulls recalls to us that union of the cranial elements which in some Vertebrates, as in Birds, is so much more complete than is normally the case with the bones constituting the human cranium.

The consideration of the relations existing between Meckel's cartilage and the summit of the hyoidean arch in man with the suspensorial and mandibular structures of lower Vertebrates, must be deferred until the internal ear is treated of, and we come to examine the essential nature of its auditory ossicles.

LESSON IV.

THE SKELETON OF THE UPPER LIMB.

1. THE bones of man's upper limb are divisible into three categories : A. Those of the shoulder ; B. Those of the arm ; and C. Those of the hand.

A. Those of the shoulder are the blade-bone, called the *scapula*, and the collar-bone, called the *clavicle*.[1]

B. Those of the arm are subdivisible into (*a*) the upper arm, and (*b*) the fore-arm.

(*a*) In the upper arm there is but a single bone, called the *humerus*.

(*b*) In the fore-arm there are two long bones placed side by side, and called the *radius* and the *ulna*.

C. Those of the hand are divisible into the bones of the wrist (or the *carpus*[2]), those of the middle, solid part of the hand, called the *metacarpus*,[3] and those of the fingers (or digits), which are called *phalanges*.[4]

2. The SCAPULA is a flat, triangular bone, with three borders and two surfaces. One of these surfaces is applied against the ribs, and is concave. It is called the subscapular fossa. The shortest of its three borders is uppermost.

The other (dorsal or outer) surface is divided obliquely into two unequal parts by a prominent ridge, called the "spine," on which account the part above the ridge is termed the *supra-spinous* fossa, and the part below it the *infra-spinous* fossa.

This spine becomes gradually more prominent from the vertebral border of the scapula, while at its outer end it expands into a large freely projecting process termed the

[1] *Clavis*, a key.
[2] From καρπός, the wrist.
[3] From μετά, after, and καρπός.
[4] Φάλαγξ, anything set in array.

acromion,[1] which is flattened in an opposite direction from that in which the scapular spine is flattened.

The superior and shortest border of the scapula exhibits a deep notch, which is converted into a foramen by means of a ligament. In front of this notch rises a strongly projecting curved process, called from its beak-like shape the *coracoid*.[2]

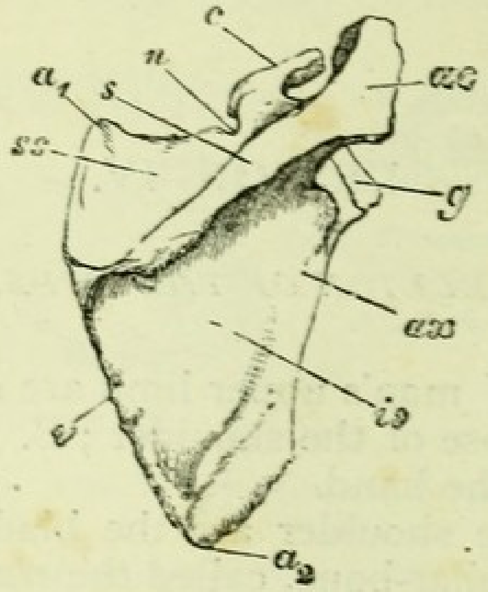

FIG. 123.—OUTER OR DORSAL VIEW OF THE RIGHT SCAPULA OF MAN.

a^1, superior angle; a^2, inferior angle; *ac*, acromion; *ax*, axillary border; *c*, coracoid; *g*, margin of glenoid surface; *is*, infra-spinous fossa; *n*, neck and supra-scapular notch, in superior border; *s*, spine; *ss*, supra-spinous fossa; *v*, vertebral margin.

The hinder border is the longest. It is called the vertebral border, because it is nearest to the backbone.

The third border (called the *axillary* border) ascends obliquely from the lower end of the vertebral border to a rounded, concave, shallow, articular surface, called the glenoid[3] cavity (into which the head of the upper-arm bone is received), and which is overhung within and in front by the coracoid process on its internal side, while the acromion overhangs it externally and behind. The part which supports the glenoid surface is termed the *neck*.

The superior and vertebral borders meet in a sharp *superior angle*, while at the junction of the axillary and vertebral borders is a flattened space for the insertion of a muscle called the teres major.

The coracoid and acromion arise from distinct centres of

[1] From ἄκρος, a summit, and ὦμος, the shoulder.
[2] From κόραξ, a crow, and εἶδος, form.
[3] From γλήνη, a superficial cavity.

ossification. The coracoid ossification contributes to form the glenoid cavity.

3. The CLAVICLE is a long cylindrical bone with a slightly sigmoid curvature, placed transversely on each side of the neck and connecting the acromion with the manubrium of the sternum. Its outer end, in childhood, bears a cartilage, termed the meso-scapular cartilage (which ultimately ossifies), and is connected with the acromion by a synovial joint. The inner end has a distinct centre of ossification (as an epiphysis), and unites with the sternum by a joint in which is interposed a fibro-cartilage (the *omosternum*) having a synovial membrane on each side of it. The clavicle is connected with the coracoid by ligament only.

4. The HUMERUS (*os humeri*) is the largest and longest bone of the upper limb, and extends from the shoulder to the elbow-joint. It is imperfectly cylindrical, with an expansion at each end. We may consider it in the position in which it is placed when the arm is dependent and the palm turned forwards.

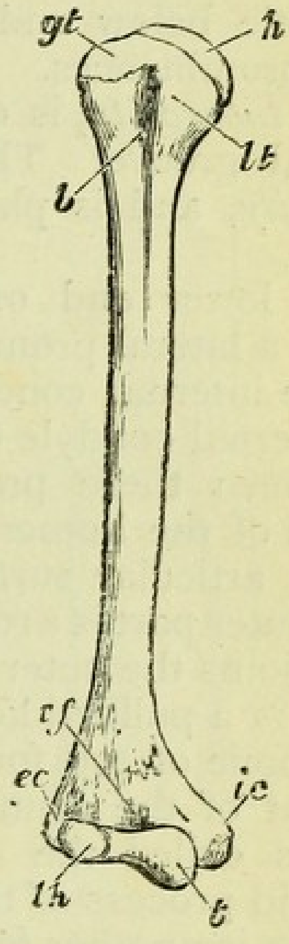

FIG. 124.—FRONT VIEW OF THE RIGHT HUMERUS OF MAN.

b, bicipital groove; *cf*, coronoid fossa; *ec*, external condyle; *gt*, great, or radial tuberosity; *h*, head of the humerus; *ic*, internal condyle; *lh*, capitellum; *lt*, lesser or ulnar tuberosity; *t*, trochlea.

The cylindrical part (or shaft) has its anterior surface marked above by a longitudinal depression, termed the *bicipital* groove, because it lodges the tendon of a muscle called the Biceps. Below and external to this is a roughened elevated tract for the insertion of the deltoid muscle.

The lower part of the shaft has its anterior surface separated from the posterior surface by two lines (or ridges), one on each side, which become well marked as they approach the lower end of the bone. The outer of these two ridges is termed the supinator, or external condyloid, ridge (for reasons which will appear), while the inner one is named the internal condyloid, or pronator ridge.

The hinder surface of the shaft presents an oblique groove (called *musculo-spiral*), passing from above downwards.

The upper end of the humerus shows a large, rounded head, covered, when fresh, with cartilage and articulated to the glenoid surface of the scapula by a synovial joint, while a fibrous bag (or capsular ligament) invests the whole articulation.

The head is placed, not on the middle of the summit, but on its inner and hinder aspect, so that its axis does not coincide with that of the shaft.

A little below and on the outer side of the head are two blunt prominences. One of these, termed the *greater* (or radial) *tuberosity*, is on the outer side of the summit of the bicipital groove. The other is called the *lesser* (or ulnar) *tuberosity*, and is placed on the inner side of the bicipital groove.

The lower end of the humerus expands considerably, having a lateral prominence, termed a condyle, on each side, but the internal condyle projects further inwards than does the external condyle outwards.

Between these projections is placed the lower articular surface of the humerus for the bones of the fore-arm.

This articular surface is irregularly concave and convex. At its outer part is a rounded prominence, called the *capitellum*, which joins the outer bone of the fore-arm or radius. Internal to this is a pulley-like surface (the *trochlea*), which joins the inner bone of the fore-arm or ulna. There is a deep cavity in front of the humerus immediately above the trochlea. This is called the *coronoid fossa*, because it receives the coronoid process of the ulna.

There is another fossa, also above the trochlea, but on the hinder surface of the humerus. This is called the *olecranal fossa*, from the part of the ulna which it receives when the arm is straightened. Sometimes a perforation connects together these two fossæ.

The ends and processes of the humerus ossify separately as epiphyses, and coalesce at about the twentieth year.

5. The RADIUS is also a long cylindrical bone, expanded more or less at each end and flattened in front, *i.e.* when the arm is dependent and the palm turned forwards.

Towards its upper end the bone, just above a roughened prominence—the "tuberosity"—is narrowed into what is called the *neck*, from which rises the *head*, concave above and articulating by a synovial joint with the capitellum of the humerus, while by a similar joint its margin plays into a concavity on the adjacent surface of the ulna.

At its lower end the radius becomes much broadened out, and its posterior surface is grooved for the passage of tendons. Its outer side is prolonged into what is called the styloid process. The lower end of the bone articulates with the wrist by a concave surface mainly supporting the hand, which is carried round with the radius in *pronation* and *supination*.

These motions have been explained in the Seventh Lesson of "Physiology," and are produced by a rotation of the radius on the capitellum.

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 downwards, 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.

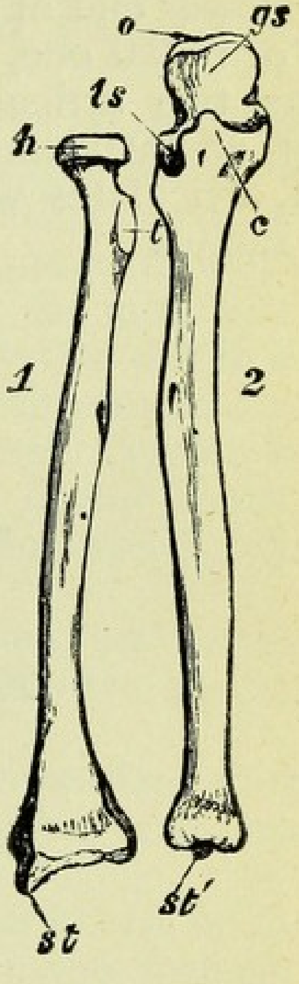

FIG. 125.—FRONT VIEW OF MAN'S RIGHT RADIUS AND ULNA.

1. The Radius: *h*, the head; *t*, tubercle; *st*, styloid process.
2. The Ulna: *c*, coronoid process; *gs*, greater sigmoid cavity; *ls*, lesser sigmoid cavity; *o*, olecranon; *st*, styloid process.

6. The ULNA is larger than the radius, and while the latter is broader below than above, the reverse condition obtains in the ulna. The shaft is flattened in front, with a sharp outer (or radial) margin, to which an interosseous membrane is attached which connects the ulna with the shaft of the radius.

Its upper end presents a deep concavity for articulation (by a hinge joint) with the trochlea of the humerus. This fossa is called, from its shape, the *great sigmoid cavity*,[1] and is divided unequally by a vertical ridge which extends between the two processes which bound the fossa above and below respectively.

[1] From Σ and εἶδος.

The lower process is called the *coronoid*,[1] and is received into the corresponding fossa on the front of the humerus.

The higher and much larger process is termed the *olecranon*,[2] and fits into the olecranal cavity on the back of the humerus.

The olecranon forms the prominence of the elbow, and terminates in a rough tuberosity.

On the outer side of the coronoid process is a small articular surface, called the *lesser sigmoid cavity*, for the border of the head of the radius, which turns upon it.

The lower end of the ulna has two eminences. The external or radial one, called the *head*, is much the larger, and presents two articular surfaces. One of these is nearly circular, and articulates with the wrist; the other, narrow and convex, articulates with a concavity on the adjacent surface of the radius.

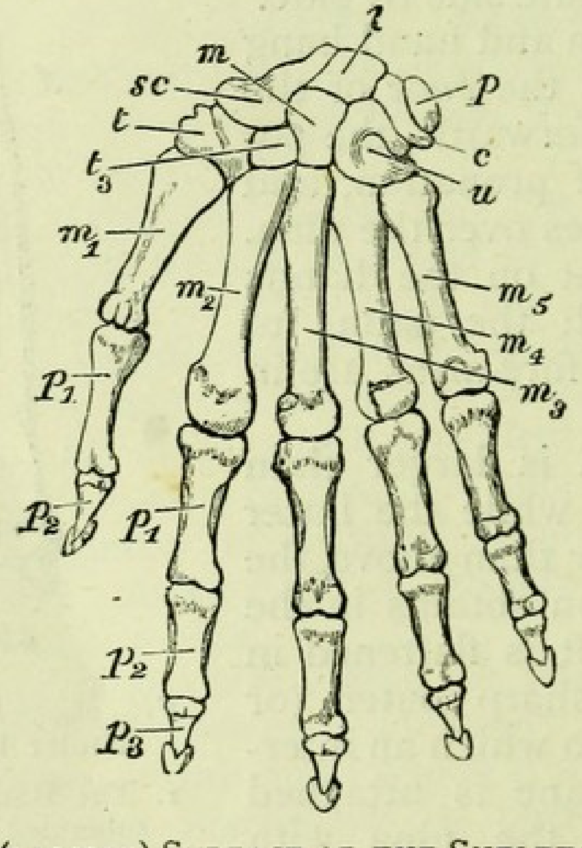

FIG. 126.—ANTERIOR (PALMAR) SURFACE OF THE SKELETON OF MAN'S HAND.

c, cuneiforme; *l*, lunare; *m*, magnum; m^1, metacarpal of thumb; m^2—m^5, metacarpals of the four fingers; *p*, pisiforme; P^1, first phalanx of the thumb and four fingers—*i.e.* of the five "digits;" P^2, second phalanx of the five digits; P^3, third, or ungual phalanx; *sc*, scaphoides; *t*, trapezium; *tz*, trapezoides; *u*, unciforme.

The internal eminence is called the *styloid process*, and does not directly articulate with the wrist.

[1] Κορώνη, the top of a curve.
[2] From ὠλένη, elbow, and κράνον, head.

7. The CARPUS consists of eight small bones arranged in two transverse series.

The bones of the upper, or proximal row, are: (1) the *scaphoides*[1] (or scaphoid bone); (2) the *lunare* (or semi-lunar bone); (3) the *cuneiforme* (or wedge-shaped bone); and (4) the *pisiforme* (or pea-shaped bone).

The first two together form an upper convex surface which fits into the distal articular cup of the radius.

The pisiforme stands out freely, and is rather a supplementary ossification of a tendon (a kind of extra ossification often occurring in different places) than a true bone of the wrist. It is a small bone.

The bones of the lower, or distal row, are: (1) the *trapezium*; (2) the *trapezoides*; (3) the *magnum*; (4) the *unciforme*.

These bones together form an undulating upper articular surface, there being a concavity on the radial side to receive a prominence of the scaphoid, and in the middle a strong convexity fitting into the cup formed by the distal sufraces of the three radial (or outer) carpals of the proximal row.

Distally, the second row of carpals presents varied surfaces for the reception of the proximal ends of the bones of the middle, solid, part of the hand (the metacarpus), which are called metacarpals.

The magnum is the largest bone of the distal series, while the unciforme articulates with and supports two metacarpals, namely, the fourth and fifth.

The trapezium presents a saddle-shaped surface to the first metacarpal, being concave in one direction and convex in another.

8. The METACARPALS are five elongated bones, each with a rounded head and a base moulded to suit the surface of the adjoining part of the carpus.

The first metacarpal (that of the thumb) is shorter than the others, and differs from them by its mode of ossification, its epiphysis being situate only at its proximal end, while in each of the other metacarpals there is an epiphysis at the distal end only.

The proximal surface of the first metacarpal is deeply concave, to suit the saddle-shaped surface of the trapezium—its support.

9. The thumb and four FINGERS are called "digits" in zootomy, each having a further distinguishing name.

Thus the first digit, or thumb, is termed the *pollex*.

[1] From σκάφη, a boat.

The second is the index.

The third is the "middle digit."

The fourth, the "ring digit."

The fifth the "little digit."

Each digit consists of three rather elongated bones, termed phalanges, except the pollex, which has but two.

Each phalanx (like the metacarpals) ossifies by an epiphysis, which is situated at its proximal end.

In each digit the phalanges become successively shorter and smaller, the third phalanx (or in the pollex the second) being very much smaller than the preceding one, but each being a little expanded at its apex to support the nail.

10. Extending one's view to OTHER ANIMALS, it may be remarked that man, inasmuch as he possesses limb-bones, resembles the great majority of Vertebrates. Still, a vertebrate animal may exist without limbs, as we see not only in the Lancelet, but also in the Lamprey, and even in most Serpents.

In that man has a pair of upper (or thoracic) and lower (or pelvic) extremities, he again agrees with most of his sub-kingdom. Still, there are many species which only possess a thoracic pair fully developed, as Cetaceans; or only one pair at all, as the Siren.

In the construction of the skeleton of the arm and hand, man follows a rule which is universal in so far as the arm-bones are attached to and suspended from a scapula which forms (together with the clavicle when this exists) the root-portion of the limb. For though the root portion may be present without its arm-bones or distal appendages (as in Anguis and others), yet the distal parts are never present when the limb-root is entirely absent.

Man agrees with the vast majority of Vertebrates in that this limb-root consists of solid parts (scapula and clavicle) destitute of any direct union with the spine. The limb-root, however, may form a solid girdle, articulated above with the spinous element of the vertebral column, which element alone interrupts the continuity of the solid zone. This is the case, *e.g.*, in *Raia clavata*. The upper ends of the girdle may not only meet, but overlap, though remaining detached from the spine. This is the case, *e.g.*, in the Toad *Dactylethra*. The shoulder-girdle may be completed superiorly by being attached to the head through special, interposed bones—the supra-clavicle and post-temporal. This is the case in most osseous fishes, *e.g.* Perch and Cod.

The bones of the superior extremity of man are of medium development as to numbers, for they may be more numerous (though rarely much so), or less numerous, since we may select a series of forms in which the number gradually diminishes to zero.

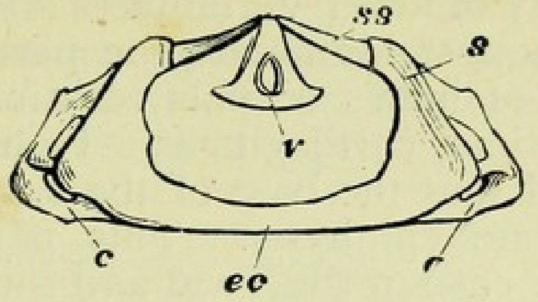

FIG. 127.—FRONT VIEW OF SCAPULAR, OR SHOULDER, GIRDLE OF THE SKATE—*Raia clavata.* (After Parker.)

This figure shows how in this animal the shoulder girdle abuts against each side of the vertebral column.

c, coracoid element; *ec*, epicoracoid element; *s*, scapular element; *ss*, suprascapular; *v*, vertebral column cut across vertically and transversely, and showing the canal for the spinal marrow in its midst.

11. The SCAPULA of man agrees in the essentials of its composition with that of every species of his class except the Monotremes. It agrees, that is, in having the coracoid process annexed to it as a mere process ending freely, and not, as in the Monotremes and in most lower Vertebrates, where the coracoid is a distinct and largely developed bone, extending down to the sternum.

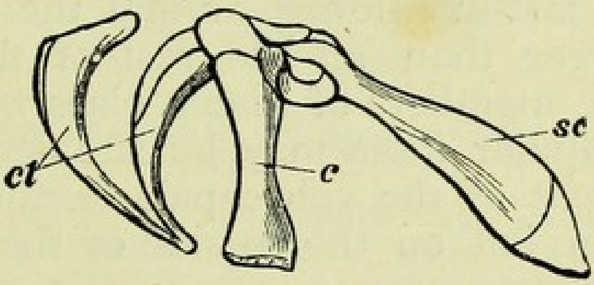

FIG. 128.—SHOULDER GIRDLE OF A BIRD (DIVER). (*After Parker.*)

c, right coracoid (its lower end abuts against the sternum—here removed); *cl*, the clavicles (merrythought); *sc*, the right scapula—the rounded glenoid surface is indicated in the scapula just where it joins the coracoid.

Man's scapula, apart from this process, is, as we have seen, flat and triangular—a shape which, though common, is by no means universal in the Vertebrata.

Thus, *e.g.*, in Birds we find the scapula to consist of a long, narrow, more or less sabre-shaped bone, though not quite always so, as it becomes considerably broadened out in the Penguin.

Even in man's own class the scapula may become much narrowed, as in the Dog; or extremely so, as in the Shrew, and still more so in the Mole.

The scapula is entirely osseous in the adult in man, who in this respect agrees with most Mammals and with Birds, but in the majority of lower Vertebrates above Fishes, and in the Ungulata amongst Mammals, the part answering to the posterior border of man's scapula remains permanently, or for a very long time, cartilaginous. In harmony with this condition, we find that the base of the scapula in man long remains a separate epiphysis. This part may be quite distinct, as is the case in the Toad and some Fishes, *e.g.* the Sturgeon and *Raia clavata*, where it bears the name of supra-scapula.

In the fact that the scapula is the great bone of the shoulder, man agrees with the rest of his class; but its size may be equalled or surpassed by the part answering to the coracoid process, as in many Birds and Reptiles, or it may be reduced to relative insignificance by the much greater development of the clavicle, as in most Fishes.

The scapula (or rather the vertebral portion of it, or supra-scapula), instead of being, as in man, widely separated from its fellow of the opposite side, may be separated from it only by the cartilaginous representative of the spinous processes of the vertebræ, as in *Raia clavata;* or the two scapulæ may overlap the one the other, as in the African toad *Dactylethra*. In the last-mentioned animal the supra-scapula is many times larger than all the rest of the bone. Comparing the other members of man's class with man, we find that the sub-scapular fossa may be situated (if we define it by the attachment of the subscapularis muscle) not on the inside, as in him, but on the outside of the blade, as is the case in the Echidna.

The spine of the scapula is a structure constant in man's class, but it may be very little developed, as in the Mole; or it may be easily overlooked, inasmuch as it forms the *actual anterior* (in man the *upper*) *border* of the scapula in the Monotremes. In these Monotremes its direction is so changed that it lies on one and the same plane with the blade of the scapula; the supra-spinatus portion of the blade being next the ribs, and the infra-spinatus fossa and sub-scapular fossa together forming its actual outer surface, the axillary margin (which ordinarily separates those two latter fossæ) aborting. The spine may be in close juxtaposition to the anterior border, as in the Dolphin. There may be a second spine behind the normal one, as is the case in the Armadillos.

An acromion process is the ordinary Mammalian termination to the scapular spine, but this may be utterly wanting, as in the Hyrax and the Giraffe. It may not only be large, but give off a distinct post-axially directed process, termed the *metacromion*, as in the Hare, Elephant, and Shrew, the acromion in the latter animal appearing to bifurcate.

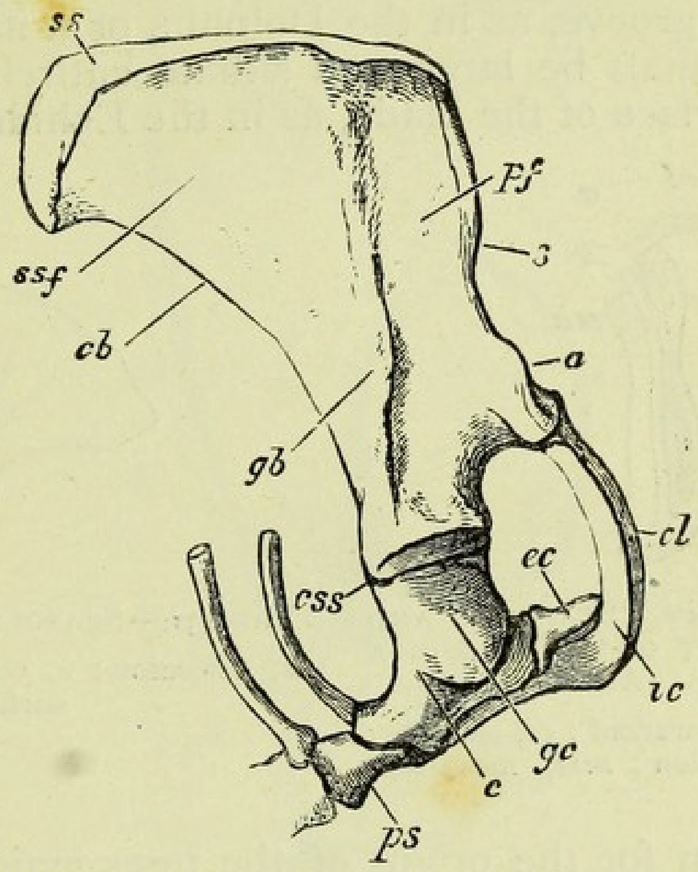

FIG. 129.—SIDE VIEW OF RIGHT SHOULDER GIRDLE OF YOUNG ECHIDNA (*Echidna hystrix*).

ss, supra-scapular epiphysis; *ssf*, sub-scapular fossa; *pf*, post-scapular fossa; *cb*, coracoid border; *gb*, glenoid border; *s*, spine; *a*, acromion; *css*, coraco-scapular suture; *gc*, glenoid cavity; *c*, coracoid; *ec*, epicoracoid; *cl*, clavicle; *ic*, inter-clavicle; *ps*, pre-sternum, or manubrium.

(*From Flower's "Osteology."*)

The acromion may join the coracoid process, and thus form a bony loop, as in the Two-toed Sloth and in Birds—the bony connexion answering to the ligament which connects the processes in man.

A distinct acromion process may be developed where there is no clavicle, as is the case in the Dolphin. It may be very long and present an articular surface for the humerus, as is sometimes the case in the Armadillos.

The articulation which takes place between the acromion and the clavicle is constant in mammals where the latter bone is developed, except in the Mole and Three-toed Sloth. In the Mole, however, there is a strong ligamentous connexion between these parts, and in the Three-toed Sloth the separation is a secondary condition, owing to the gradual atrophy of the acromion which was primitively connected with the clavicle.

The supra-spinatus fossa may be about equal to the infra-spinatus one, as in the Dog and Shrew, or larger than it, as in the Lion and in Sloths. It may, on the contrary, be little more than a groove, as in the Dolphin, or it may (and this is very exceptional) be large and situate entirely on the inner (or body) surface of the blade, as in the Echidna.

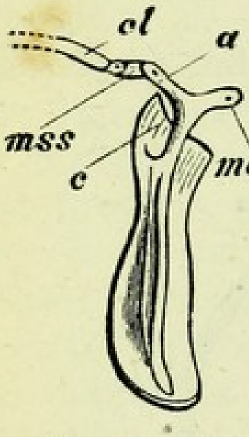

FIG. 130.—RIGHT SCAPULA AND SCAPULAR PART OF CLAVICLE OF A SHREW—*Sorex*. (After Parker.)

a, acromion ; *c*, coracoid ; *cl*, clavicle ; *ma*, metacromion ; *mss*, meso-scapular segment.

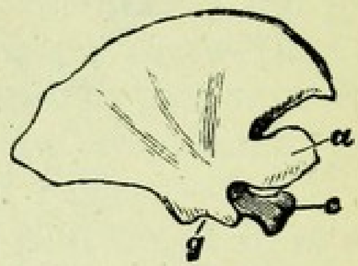

FIG. 131.—SCAPULA OF A PORPOISE.

a, acromion ; *c*, coracoid ; *g*, glenoid surface.

The portion for the origin of the teres major muscle may be greatly produced, as in the Armadillos and even in Baboons.

The superior border of the scapula may be very much longer than the base, as in Ungulates, and enormously so in the Mole. It may, on the contrary, be relatively shorter even than in man, as in the Chimpanzee. It may be very convex, as in the Mandrill Baboon ; and, most strange of all, it may form what is apparently the posterior margin of the scapula, as in the Echidna.

The supra-scapular notch may be converted into a foramen, as even in one of man's order (*e.g.* in *Mycetes*), and in the Two-toed Sloth. The notch, however, may be entirely absent, as in the Deer and many others.

The base may be much the shortest of the three borders, as in the Dog and Ungulates, and especially in the Mole. It may, however, be very much elongated, as in the Chimpanzee and Dolphin.

The axillary border is, of course, drawn out where the scapula is long and narrow. The most singular situation of this border is found in the Echidna, where it appears as a slight ridge traversing the outside of the blade of the scapula.

The postero-superior angle of the scapula may be rounded off, as in the Dog and many others. It may, on the other hand, be very prominent, as in the Dolphin. The inferior angle may also be either sharp or rounded.

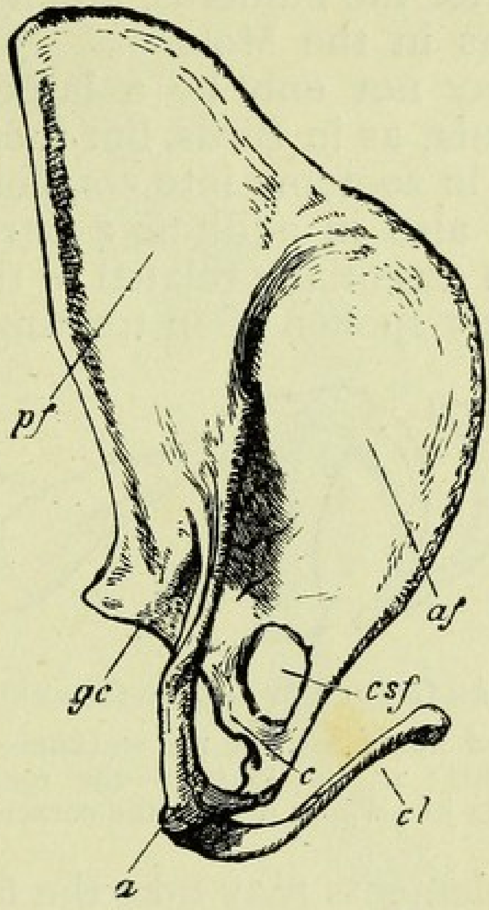

FIG. 132.—RIGHT SCAPULA AND CLAVICLE OF TWO-TOED SLOTH (*Cholœpus Hoffmanni*).

af, pre-scapular fossa ; *pf*, post-scapular fossa ; *gc*, glenoid cavity ; *a*, acromion ; *c*, coracoid ; *csf*, coraco-scapular foramen ; *cl*, clavicle.

(*From Flower's "Osteology."*)

The neck of the scapula is always the narrowest part of that bone in man's class, but when we descend we may find it to be the widest part, as in some Fishes, e.g. *Raia clavata*.

Passing now to the second part of the scapula, in man called the coracoid process, we shall find that, rudimentary as is this part in him compared with its condition in lower forms, it is nevertheless not at its minimum, for it may be, as in Ungulates, *e.g.* the Deer, quite rudimentary. On the other hand, it may be relatively larger than in man, as in the Two-toed Sloth, where it joins the acromion. It may be not only long, but also forked, as in the little Pipistrelle Bat. It may also join the clavicle, as in the Three-toed Sloth and Mole.

As has been said, this part may even in man's class (viz. in Monotremes) be a large distinct bone connecting the scapula with the sternum, and having an additional flat bone placed in front of the inner end of the coracoid, called the epicoracoid, and a distinct rudiment of the epicoracoid may be found in a higher Mammalian form, *e.g.* in *Sorex.*

The coracoid shares with the scapula the office of forming the glenoid surface for the humerus, and it may become fused with the clavicle, as in the Mole.

The coracoid may not only be a large bone rivalling or exceeding the scapula, as in Birds, but there may be complex structures divisible in zootomy into coracoid and epicoracoid, as before said, and also in addition a part termed pre-coracoid, which, though essentially related to the coracoid, will yet be more conveniently spoken of in treating of the clavicle.

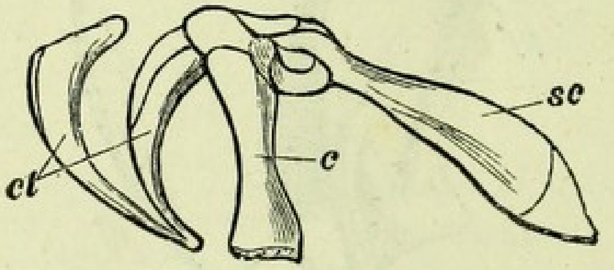

FIG. 133.—SHOULDER GIRDLE OF A BIRD (DIVER). (*After Parker.*)

c, coracoid (its lower end abuts against the sternum—here removed); *cl*, the clavicles (merrythought); *sc*, the scapula—the rounded glenoid surface is indicated in the scapula just where it joins the coracoid.

These coracoid elements may take the form of a large cartilaginous sheet passing down from the glenoid surface to the middle line of the breast, as in Efts; or may appear as two bones so passing down on each side, one in front of the other, as in the Frogs; or as a large sheet of bone and cartilage often more or less perforated, as in many Lizards.

Instead of a single glenoid surface (as we find in all Vertebrates above Fishes which have pectoral limbs), we find what may possibly be several distinct glenoid surfaces, as *e.g.* three in *Raia clavata.*

Where the coracoids are in the form of large lamellæ, they may overlap one the other, as in Batrachians, e.g. *Salamandra* and the Frog.

The coracoid and scapula may form one cartilaginous whole, while the supra-scapula remains distinct, as in *Raia* *clavata*. They may form one osseous whole in Birds (*e.g.* the *Struthionidæ* or *Ratitæ*), continuing on in one main direction. They may, on the contrary, as in all carinate, or ordinary Birds, be so placed that the coracoid forms with the scapula an acute angle open backwards.

To the parts which represent the scapula and coracoid in osseous Fishes, the names of ulna and radius have sometimes been respectively applied. The coracoid may attain a prodigious size, as *e.g.* in the Opah fish (*Lampris*).

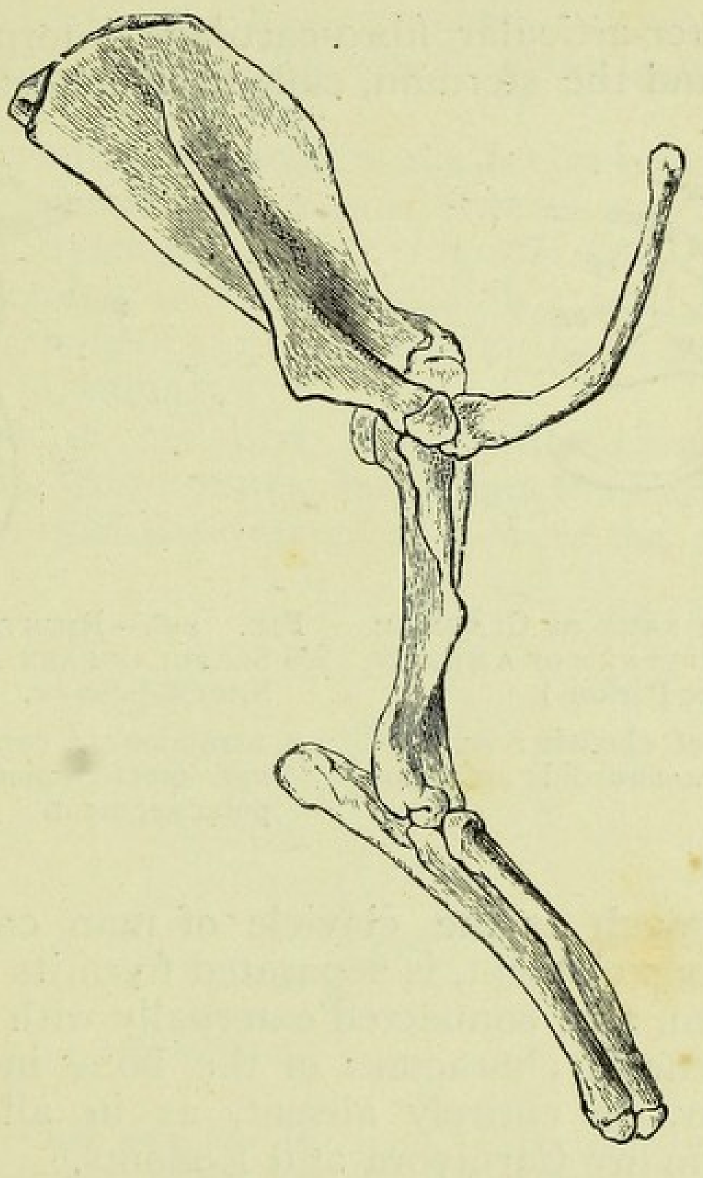

FIG. 134.—BONES OF THE RIGHT ARM AND SHOULDER OF THE SMALL TANREC—*Hemicentetes*.

This view shows the elongated *scapula* with blunt *metacromion* and very small *coracoid*; also the largely-developed *clavicle* attached to the end of the *acromion* and projecting freely—the humerus with the prominent *deltoid ridge* (or crest) and the *radius* applied closely in front of the *ulna*, which latter bone has a well-developed *olecranon*.

12. The apparent simplicity of the CLAVICLE in man would hardly allow of a correct *à priori* conjecture as to the

complexity of the parts which may represent, or most nearly correspond with it in the lower, and especially the lowest, Vertebrates.

In fact, however, the clavicle of man is made up of four parts, as has been noted. Thus we have—

(1) The body of the bone.

(2) The acromial end of the clavicle, remaining cartilaginous in the young state, called the meso-scapular segment.

(3) The sternal epiphysis of the clavicle, called the precoracoid.

(4) The inter-articular fibro-cartilage interposed between the clavicle and the sternum, called the omosternum.

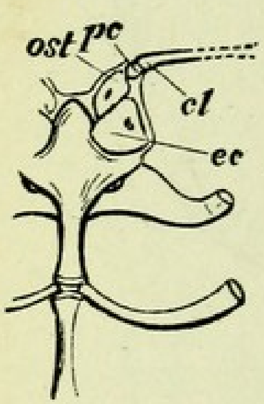

FIG 135.—INNER PART OF CLAVICLE AND PART OF STERNUM OF A SHREW —*Sorex*. (After Parker.)

cl, sternal part of clavicle ; *ec*, epi-coracoid ; *pc*, pre-coracoid ; *ost*, omosternum.

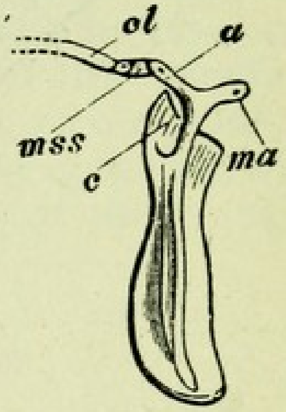

FIG. 136.—RIGHT SCAPULA AND SCAPULAR PART OF CLAVICLE OF A SHREW—*Sorex*. (After Parker.)

a, acromion ; *c*, coracoid ; *cl*, clavicle ; *ma*, metacromion ; *mss*, meso-scapular segment.

Now, inasmuch as the clavicle of man consists of only one conspicuous element, is separated from its fellow clavicle by the sternum, and connected externally with the acromion, it has the general characters of the bone in his class. It may, however, be entirely absent, as in all Cetacea and Ungulata, in many Carnivora and Rodents.

It may, on the contrary, be very short and rudimentary, and suspended by long ligaments both to the scapula and sternum, as in the Guinea-pig and Rabbit.

It may be separate from its fellow of the opposite side and from the sternum, as in the Cassowary and Emeu.

It may—though this is very rare—have ultimately coalesced with the coracoid, so as to form a complex single bone of double nature, as in the so-called clavicle of the Mole, which helps to form the articulation of the humerus.

The clavicles may be fused together in the middle line, as in the merrythought of Birds.

The meso-scapular segment never appears to become very large, but the pre-coracoid part becomes very considerable in the Ostrich, where a foramen indicates the line of demarcation between it and the true coracoid, and it is large in many Lizards, *e.g.* the Monitors. In Chelonians the pre-coracoid is a large bone descending from the glenoidal region downwards and inwards towards the ventral shield of the carapace. It has been spoken of as a true clavicle, as also the anterior of the two bars which, in the Frogs and Toads, pass inwards from the scapula, but which seems to be really a pre-coracoid.

The last element, the omosternum, becomes amongst Mammals very conspicuous in certain Shrews and Mice; also in certain tailless Batrachians, e.g. *Pseudis* and *Pipa*. It may be that this element is the same as that next to be noticed, and which otherwise has no representative in man, or in any but the lowest Mammals.

The element in question is the inter-clavicle, which is enormous in the Monotremes, and forms the bulk of that large T-shaped bone which prolongs as it were the manubrium of

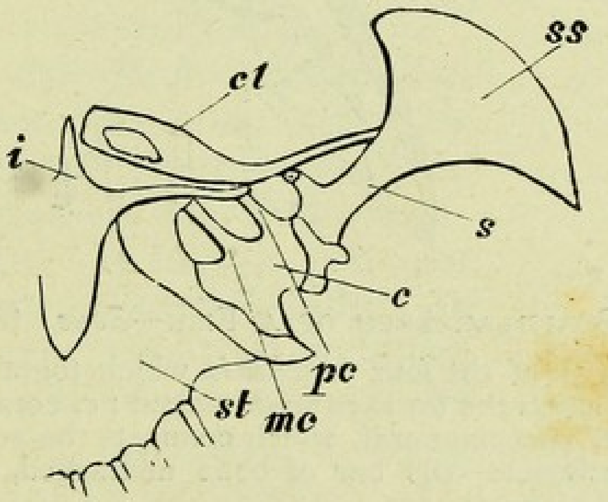

FIG. 137.—FRONT VIEW OF LEFT HALF OF SHOULDER-GIRDLE OF A GECKO LIZARD—*Hemidactylus*. (After Parker.)

c, coracoid; *cl*, clavicle; *i*, inter-clavicle; *mc*, meso-coracoid; *pc*, pre-coracoid; *s*, scapula; *ss*, supra-scapula; *st*, sternum.

the sternum, and which bears on its diverging arms the small splint-like clavicles. The same element is more or less similar in shape in many Lizards, e.g. *Iguana* and *Monitor*. It may be cruciform, as in *Cyclodus*, or a simple forwardly directed ossicle, as in the Crocodile, or a median expanded lamella of bone or cartilage, as in *Anguis* and Chelonians.

It may be small and serve to connect the clavicles, as in Birds, where it forms the middle of the merrythought. It may be very large and bifold, as in many Fishes, e.g. *Cottus* and the Sturgeon.

The true clavicle, more or less cylindrical or at least slender in Mammals and Birds, may become expanded in Lizards (e.g. *Hemidactylus*, *Cyclodus*, and especially *Trachydosaurus*).

In Chelonians also the clavicles are greatly expanded and form the two foremost bones of the ventral part of the carapace, the median one immediately behind them being the inter-clavicle.

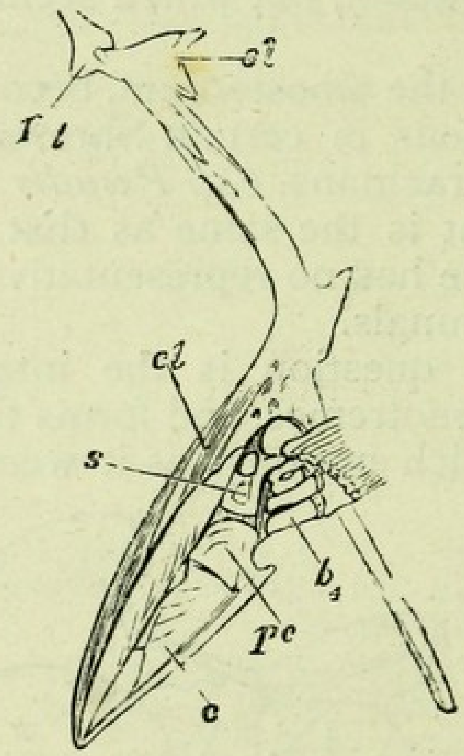

FIG. 138.—SCAPULAR ARCH OF A FISH—*Zeus*. (After Parker.)

b^4, the fourth or lowest of the four *brachials* which together may represent the humerus, and to which the fin rays are attached ; *c*, coracoid ; *cl*, clavicle ; *pc*, pre-coracoid ; *pt*, post-temporal, which connects the scapular arch with the skull ; *sl*, supra-clavicle—the bar of bone unmarked, which descends backwards, is the *post-clavicle*.

The great size of the clavicle here and in *Trachydosaurus* prepares us for the still vaster development of this part in bony Fishes, where the clavicles become enormous, and may not only be provided with a distinct inter-clavicle, but also each with a distinct portion above—the supra-clavicle (as in the Dory, *Zeus*, the Sturgeon and others), and besides this with a posterior element, a post-clavicle, as in the Dory, Perch, and Cod.

Thus the clavicle of man, instead of being the simple structure which it seemingly is, really represents some elements which properly belong to the coracoid, and other elements which may greatly increase both in size and complexity in other animals. At the same time its inconstancy is such that it may utterly abort, while the scapula and even the coracoid element are largely developed.

13. That important bone of the human skeleton, the HUMERUS, is constantly present in Vertebrates above Fishes, wherever there is an upper limb at all, although differing in size and shape. It never, however, seems to be present where there is no representative of the hand—in this respect, as we shall see, differing from the thighbone in the relation of the latter to the foot.

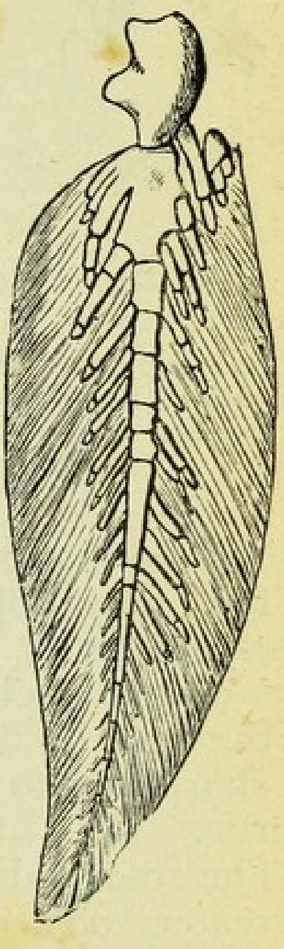

FIG. 139.—CARTILAGINOUS SKELETON OF A LIMB OF *Ceratodus*. (After Günther.)

The large upper piece articulates with the limb root.

In the lowest Vertebrates, *i.e.* in all Fishes, it is difficult to say what certainly corresponds with the humerus of man, but very probably the several bones or cartilages which articulate with the coracoid and scapula (at the several glenoid surfaces before described) may be such representatives.

In this case it may be said (1) either that several (two to five) bones or cartilages together represent man's humerus, or (2) that each of these is in fact a rudimentary humerus, so that a fish has thus several humeri on each side. It is possible, however, that this bone (or perhaps the next limb segment—radius and ulna) may be represented by a single cartilage—as in *Ceratodus*.

Leaving, however, these members of the lowest Vertebrate class, we shall find that higher forms show the several parts of man's humerus to be capable of different degrees of development, yet that on the whole great variations are rare.

As being the largest bone of the arm the humerus of man follows the general rule, but it may be much exceeded in size by a bone of the fore-arm, as in the Bat and Eagle, while its length may be quite insignificant compared with that of the entire limb, as in the Dolphin. Its length may, however, exceed that of all the rest of the limb put together, as in the Apteryx. It may also exceed the length of the whole body, as in the Pelican ; while a few Birds, *e.g.* the Martins, have it remarkably short.

In its being cylindrical in shape man's humerus is normal, but it may be almost as broad as long, as in the Mole and some Cetacea. The head of the humerus is generally less spheroidal than in man, with high projecting processes (the tuberosities), as in the Carnivora, *e.g.* the Dog. It may have the form of a transversely extended articular ridge, as in Birds.

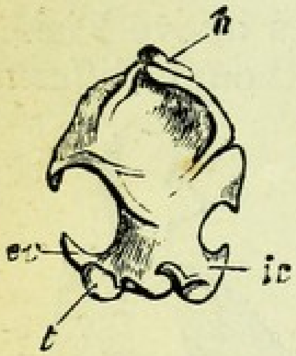

FIG. 140.—RIGHT HUMERUS OF A MOLE.

ec, external condyle ; *h*, head ; *ic*, internal condyle ; *t*, capitellum.

The shaft of the bone may be twisted like the letter S, as in the Tortoises, but that twist of the shaft which we find in man is peculiar to him and to the highest Apes, though there is something like it in Birds.

The greater (radial) and lesser (ulnar) tuberosities are very constant structures, one or both appearing down to the lowest Batrachians.

They may project much more than in man (as *e.g.*, amongst many others, in the Dog and Sheep), or the two may be fused into one, thus obliterating altogether the bicipital groove, as is the case in the Cetacea ; or they may project much and so sharply as to make that groove a very deep one, as in the Turtle.

The so-called "lesser" tuberosity may be as large as the "greater" one, or even come to exceed it in size, as in the Two-toed Sloth, the Bat *Pteropus*, and the Lizard *Uromastix*. Beneath the lesser tuberosity a deep cavity may exist, as in Birds : this is to allow air to enter the air-cavity within the bone, many bones in many Birds being thus filled with air instead of marrow.

The rough surface for the deltoid is in man's humerus but a faint indication of what may in other forms, *e.g.* the Seal, Mole, Beaver, &c., be a very prominent ridge.

The lower end of the bone may be either more expanded relatively than in man, or less so. Thus, *e.g.*, the condyles may be very greatly produced, as in the Mole, Armadillos, and Echidna, or they may be quite rudimentary, as in the Deer and Hare.

Very often a foramen may exist above the internal condyle, as *e.g.* in the Wombat. This serves to transmit the median nerve and brachial artery, which are thus protected by bone in a way found only by a very rare exception indeed, if ever, in man. There may be a notch or a foramen above the *external* condyle, as in some Lizards, e.g. *Psammosaurus.*

The transverse extent of the inferior articular surfaces of the humerus of man is greater than in very many forms, on account of the articular surface for the radius coming to be in front of, instead of at the side of, that for the ulna. We see this very distinctly, *e.g*, in the Dog.

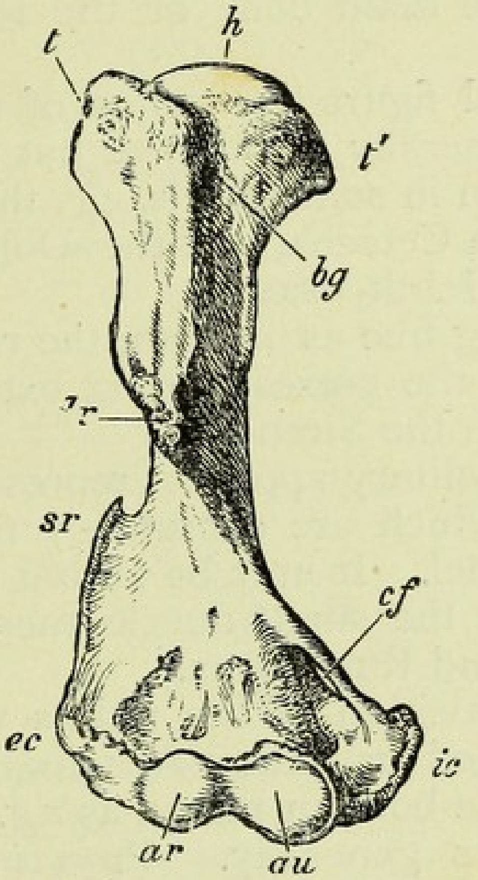

FIG. 141.—ANTERIOR SURFACE OF RIGHT HUMERUS OF WOMBAT (*Phascolomys vombatus*).

h, head ; *bg*, bicipital groove : *t*, great or radial tuberosity ; *t'*, small or ulnar tuberosity ; *dr*, deltoid ridge ; *sr*, supinator ridge ; *cf*, supra-condylar foramen ; *ec*, external condyle ; *ic*, internal condyle ; *ar*, articular surface for radius ; *au*, articular surface for ulna.

(*From Flower's " Osteology."*)

The fossæ for the coronoid process and olecranon, which sometimes communicate by a perforation in man's humerus, may do so normally and constantly, as *e.g.* in the Hare.

Rarely (as in some Tailed-Batrachians) a dense ligament may connect the head of the humerus with the glenoid cavity, as we shall see that the head of the thighbone is normally connected with the cavity which receives it.

14. The RADIUS is a bone constantly present and distinctly represented, wherever an arm exists, in all Vertebrates above Fishes. In Fishes its exact representative cannot be determined. The ossicles or cartilages, however, which may be distally annexed to the representatives of the humerus, probably as a whole represent both the radius and the ulna.

In the constancy of its development the radius shows its generally greater importance as the main bone of the fore-arm, when compared with the ulna, which latter may more or less completely abort.

In Birds, however, it is subordinate in development to the ulna, which is the main bone of the fore-arm in them, *e.g.* the Eagle.

In its elongated figure the radius of man agrees with the same bone as generally developed, but it may be shortened and flattened even in some Birds, *e.g.* the Penguin, and very much more so in Cetacea, *e.g.* the Dolphin, and still more so in the extinct Ichthyosauria.

Instead of being free as in man, the radius may anchylose at each end with the corresponding extremities of the ulna, as is the case with the Sirenia.

It may be the solitary apparent representative of the bones of the fore-arm, which are completely fused together, as in the Frog and Camel. It may be all but the only bone of the fore-arm, through the small development of the ulna, as is the case in Bats and Ruminants.

That crossed position of the radius with relation to the ulna which is called pronation in man, is the constant and only position of the bone in many, as *e.g.* the Dog, Elephant, and hoofed beasts generally. Pronation and supination, however, are not confined to man. They exist sometimes very distinctly, as *e.g.* in the Apes and Sloths.

No motion of the kind is possible in many forms in which the radius does not cross the ulna, as in Bats and Birds, where such a flexibility of the limb would be fatal to flight. Pro- and supi-nation are also impossible in the Cetacea, where there is no movable elbow-joint at all.

But the limbs may permanently retain a position which indeed is primitive and temporary in man ; that is to say, there may be no crossing of the bones of the fore-arm, and yet the whole dorsum (or extensor surface) of the limb may be turned outwards somewhat in the position in which a man puts his arms when, resting on his two palms, he stoops to drink from a pool between them. Even thus the primitive position cannot be quite assumed by the adult human being, though it is the permanent condition of some Reptiles, especially the Chelonians.

The head of the radius is often much larger relatively than in man, as *e.g.* in the Dog and Ruminants.

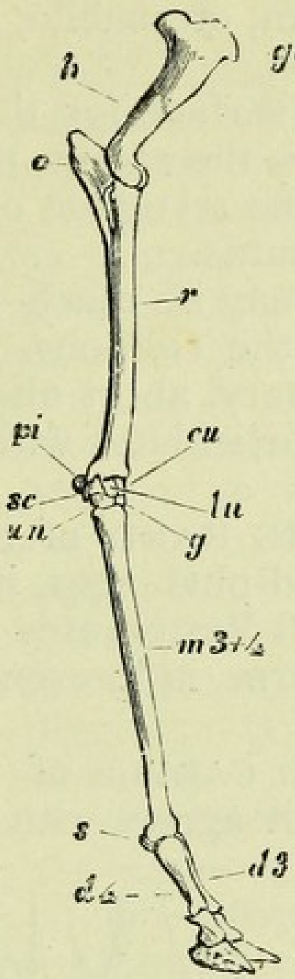

FIG. 142.—RIGHT PECTORAL LIMB OF A GIRAFFE.

cu, scaphoides; d^3, proximal phalanx of third digit: d^4, proximal phalanx of fourth digit; *g*, magnum; *gt*, great tuberosity of the humerus; *h*, shaft of the humerus; *lu*, lunare; m^{3+4}, united metatarsals of third and fourth digits; *o*, olecranon; *pi*, pisiforme; *r*, radius; *sc*, cuneiforme; *un*, unciforme.

15. As with the radius, so with the ULNA, we can only employ Vertebrates above Fishes for comparison.

In the proportion it bears to the radius, man's ulna agrees on the whole with the relation obtaining in the majority of forms.

It may, however, be larger and more important than the radius, as is the case in Birds, *e.g.* the Eagle. On the contrary, it may be very much smaller and more or less abortive, as in Ruminants and Bats. That the proportionate size of this bone has no relation to flight is shown by the just-mentioned fact, that it is the larger bone in Birds and the smaller one in Bats.

The olecranon process of man is larger than in many forms; thus *e.g.* it is relatively larger than in Birds. It is, however, much larger relatively than in man in many Mammals, even *e.g.* in Baboons, and still more in Ungulates, the Monotremes, and the Mole. There may be a detached sesamoid ossicle at the end of the olecranon, reminding the observer of the knee-pan, or patella, of the leg. This is the case in some Bats.

The ulna's articular surface for the humerus may merely complete that offered by the radius, the two together forming a single concavity for the reception of the humerus. This is the case, *e.g.*, in Ruminants.

The styloid process may be much more prolonged than in man: we find it so in the Gibbons. The distal part of the ulna may, on the contrary, abort altogether, as in the Bats. It generally, however, articulates with the carpus directly, as the radius does.

16. Inasmuch as THE HAND of man is made up of the carpus, metacarpus, and phalanges, it agrees with the corresponding segment in all Vertebrates above Fishes; where, if any element of the arm is present, the hand is present likewise.

17. Inasmuch as the CARPUS of man consists of a few relatively small bones, it agrees with that of all other Verte-

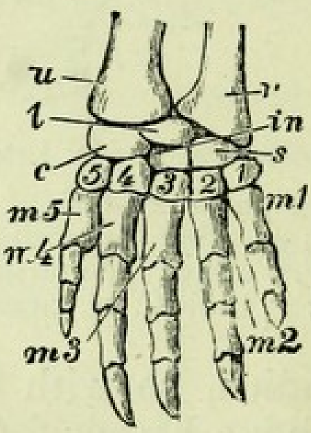

FIG. 143.—DORSAL SURFACE OF SKELETON OF RIGHT HAND OF THE TORTOISE *Chelydra.* (After Gegenbaur.)

c, cuneiforme; *in*, intermedian (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.

brates above Fishes, except that in some Tailed-Batrachians and Cetaceans the parts are more or less permanently cartilaginous. The number of carpal bones, however, may be increased to ten, as in Chelonians, or it may be reduced to two, as in Birds.

Very rarely, as in the Crocodile, the two proximal bones may be so much longer than the others as to take on somewhat the character of "long bones," and to constitute by themselves another limb segment.

18. The BONES OF THE FIRST ROW of the carpus, except the pisiforme, may be represented by one single bone, as in *Pteropus*.

Inasmuch as the *scaphoides* articulates with the radius, it has a character which is constant. The distinctness which it possesses in man is by no means universal. Thus the scaphoid coalesces with the lunare in the Carnivora and many other Mammals, and also probably in the Crocodiles. It unites with the cuneiforme in addition in *Pteropus*. It may coalesce with the trapezium, as in the Three-toed Sloth. It may become a considerably elongated bone, as in the Crocodile.

On the outer (radial) side of the scaphoid we often find a small ossification of a tendon, or sesamoid ossicle, corresponding with that sesamoid ossicle of the ulnar side, which is counted as a carpal, and called the Pisiforme.

This radial sesamoid ossicle is found even in Apes, but it attains its maximum in the Mole, where it strengthens and broadens the hand for digging. It is found even in some Reptiles, as *e.g.* in *Emys europea*.

An extra bone which exists in many Vertebrates, but not in man (and which goes by the name of *os centrale*, or *intermedium*), is most probably a dismemberment of the scaphoid. It is present and distinct in the Apes, except the very highest, and many other forms, including most Reptiles and Batrachians. The form of the scaphoid in *Emys europea* seems to show that the centrale is a dismemberment of the scaphoid, as indeed does its position in the Orang.

This conclusion is indicated by the occasional ossification of the scaphoid from two centres, in the class Mammalia.

The centrale may form a very large and conspicuous part of the carpus, to the abortion of any representative of the trapezium. This, *e.g.*, is the case in the Crocodile; and if the centrale be a dismemberment of the scaphoid, then, considering the length and size of the undoubted scaphoid or scapho-lunar bone in the Crocodile, the equivalent of man's scaphoid forms alone the larger half of the carpus in that reptile. Again, the centrale may form a singularly conspicuous part, as in the Chameleon, where it is surrounded by the more distal bones of the carpus, which have respectively coalesced with their adjacent metacarpals.

As has been already said, the *semi-lunar bone* may coalesce with the scaphoid in many animals, *e.g.* the Dog. It may, on the contrary, unite with the cuneiforme, as in the Salamander and Triton, and probably in Birds. It seems also to be generally absent as a distinct bone in Reptiles other than Chelonians. Thus its distinctness in man is a rather exceptional character.

The separate and well-developed condition of the *cuneiforme* in man is one which characterizes it generally, it being one of the constant carpal bones; the only noteworthy deviations are that, as just said, it may coalesce with the lunare, or even with the scaphoid also, as in *Pteropus*; or that it may be very considerably increased in length, as in the Crocodile. It may be relatively larger than in man, as in the Turtle; or smaller, as in the Mole.

The inconstancy of the *pisiforme* is a consequence of its being really no true carpal, but only an accessory sesamoid, like the radial ossicle spoken of in noticing the scaphoid. Thus it is often absent, as in many Cetacea, the Sirenia, Birds, many Reptiles, and all Batrachians; while it is very small in Bats, Seals, and others. It may be much larger and longer relatively than in man, as *e.g.* in the Carnivora.

19. The BONES OF THE SECOND ROW are by no means so constant in number or development as are those of the first

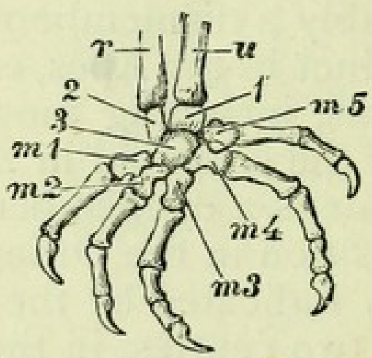

FIG 144.—Left Hand of Chameleon, showing the opposition between the two ulnar and the three radial digits.

m^1—m^5, the five complex bones formed of the union of each metacarpal with the corresponding distal carpal bone; *r*, radius; *u*, ulna; 1, ulnar proximal carpal bone; 2, radial proximal carpal bone; 3, intermedium or centrale.

row. They may coalesce with the metacarpals, as is the case in the Chameleon.

The importance and size of the *trapezium* in the human carpus, owing to the relation it bears to the development of man's thumb, are very different from what we see in some members of man's class, and even order.

The saddle-shaped surface for articulation with the first metacarpal is not so well developed in any other form as it is in man.

The trapezium may be quite rudimentary, as in *Chœropus*,

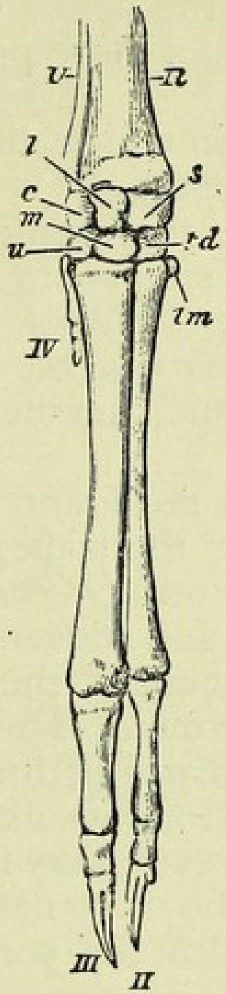

FIG. 145.—BONES OF MANUS OF *Chœropus castanotis.*

c, cuneiforme; *l*, lunare; *m*, magnum; *R*, radius; *s*, scaphoides; *td*, trapezoides; *tm*, trapezium; *U*, ulna, *u*, unciforme; *II.*, *III.*, and *IV.*, second, third, and fourth digits.

(*From Flower's "Osteology."*)

or altogether wanting, as in the Horse, Sheep, Pig, Dolphin, Salamander, &c.

As to Birds, no distinct trapezium is distinguishable; and the same is the case with Crocodiles, but a trapezium exists in many Lizards. As has been said, it may, as in the Three-toed Sloth, coalesce with the scaphoides.

The *trapezoides* is a more constant bone than is the preceding one, as it seems to exist in all Mammals which have a carpus, though its existence is not to be made out in Birds, or clearly so in Crocodiles. It may be relatively smaller or larger than it is in man, and it may, as in the Three-toed Sloth, coalesce with the os magnum.

The *os magnum* may be much smaller relatively than in man (as *e.g.* in the Bear and Hare) ; or relatively larger (as in the Hyrax); or it may seem to abort altogether, as in Birds. Compared with the bones of the second row only, it may be, as in the Horse, a more predominant bone than it is in man.

The undivided state in which the *unciform bone* exists in man is universal in his class.

It may, however, be represented by two distinct bones corresponding with and supporting the fourth and fifth metacarpals, as in *Chelonia, Chelydra*, and *Salamandra*. There may be no bone whatever capable of identification with it, as in Birds. It may be much smaller or larger relatively than it is in man.

An additional ossicle not found in man may be present in the ligament connecting the trapezium and unciform bones. This is the case in the Potto (*Perodicticus*).

20. The distinctness and development which the METACARPUS or middle segment of the hand attains in man are characters which are normal. The somewhat opposed position of the first metacarpal in him is only found in a few Mammals besides—in Monkeys and Lemurs.

The metacarpals, however, may fuse with the distal carpals —the trapezium with the first metacarpal, as in the Three-toed Sloth, or all five with the corresponding carpals, as in the Chameleon.

A more complete opposition may obtain, however, than that which exists between the first and the other metacarpals in man ; as is shown by the Chameleon, in which the three radial metacarpals are as strongly as possible opposed to the two ulnar ones.

In the number of these bones and their sub-equality of development man agrees with many Vertebrates above Fishes. Nevertheless, the number may be much reduced, and the proportions of the several bones may vary in different modes.

Thus there may be but a single metacarpal (the third), with rudiments of two others, as in the Horse; or there may be but a single bone, which consists of the third and fourth fused together, as in the Sheep, Deer, &c.

Again there may be but two, the second and third, with another rudimentary metacarpal (which answers to man's fourth), as in *Chœropus;* or the same two with a rudiment of the first metacarpal also, as in *Cholœpus.*

We may have the second and third metacarpals well de-

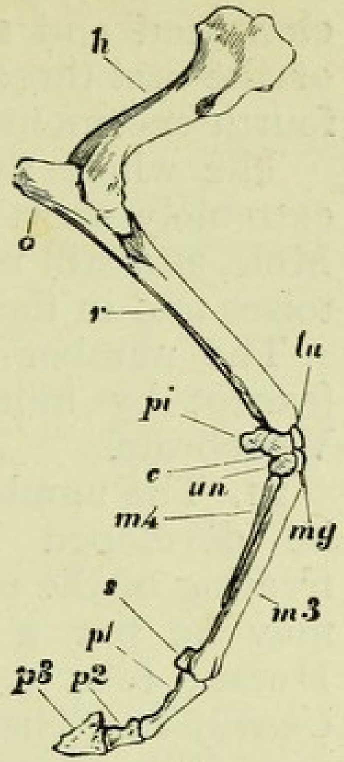

FIG. 146.—RIGHT PECTORAL LIMB OF HORSE.

c, cuneiforme ; *h*, humerus ; *lu*, lunare ; m^3, metacarpal of the third digit—the only one fully developed ; m^4, rudimentary fourth metacarpal ; *mg*, magnum ; *pi*, pisiforme ; p^1, proximal phalanx ; p^2, middle phalanx ; p^3, third or ungual phalanx ; *s*, sesamoid ; *un*, unciforme.

veloped, with a rudiment also of the first, all three being fused together into a single bone—as is the case in Birds.

There may be but three sub-equally developed, and these may be the second, third, and fourth, as in *Proteus* and Rhinoceros ; or they may be the first, second, and third, as in *Seps tridactylus.* The three may be anchylosed together at their proximal ends, as in the Three-toed Sloth.

FIG. 147. — PALMAR VIEW OF LEFT HAND OF SEPS TRIDACTYLUS.

(*After Fürbringer.*)

There is here but a minute rudiment of the 4th digit. The pollex, index, and third digit are well developed.

The metacarpals may decrease in size from the first to the fifth, as in Seals ; or increase from the first to the fifth, as in the Manatee.

They may be singularly unequal, the third being by far the thickest and extremely short, as in the Great Armadillo ; or the third being far the slenderest and extremely long, as in the Aye-aye.

The first may disappear or be rudimentary, as happens in very many forms; or the second digit alone may be very reduced, as in the Potto.

The first may be short and the four others exceedingly elongated and slender, as in the Bats; or the first three may be short and the fourth enormous, as in the Pterodactyles.

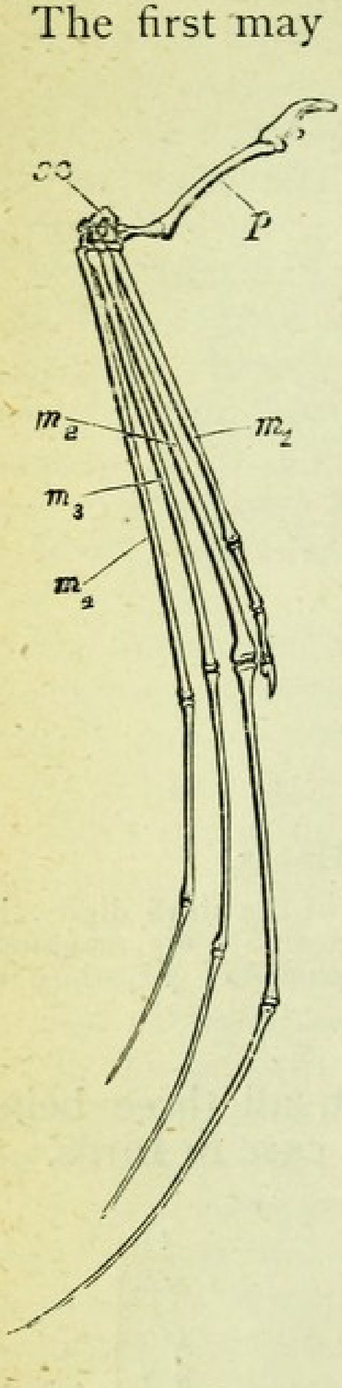

FIG. 148.—HAND OF BAT (*Pteropus*).

m^1—m^4, metacarpals of the four fingers; *p*, pollex, with a very short metacarpal, *sc*, scaphoides.

The whole five metacarpals may be extremely short and stunted, as in the Mole, and still more so in the Land Tortoises and in the Ichthyosaurus.

The number five is never increased (except by monstrosity) in any known Vertebrate.

21. The number of DIGITS which may be developed has been indicated in treating of the metacarpus. Thus there may be but a single digit, as in the Horse; two, as in Ruminants, and in *Chœropus.* There may be three, as in the Rhinoceros, *Proteus*, and *Seps* (second, third, and fourth, or first, second, and third); or, as is very often the case (*e.g.* Pig, Dog, &c.), there may be four.

The digits are never certainly more than five (except by monstrosity), although in the Ichthyosaurus extra marginal bones give the appearance of more. The filamentary bones which terminate or fringe the fins of Fishes are not digits at all, but are dermal ossifications called "fin rays," which will be spoken of with the rest of the external skeleton.

When a digit is wanting, it is generally the pollex, as in Spider Monkeys, but it may be the fifth, as in Pterodactyles, or the fourth and fifth, as in Birds.

The thumb (pollex) may be more or less opposable, as in most Monkeys and Lemurs; or two digits may be opposed to three, as in the Chameleon.

The second digit may be greatly reduced, as in the Potto: or the third may be disproportionately slender, as in the Aye

Aye; or thick, as in the Great Armadillo. The digits may be enormously long, as in the Bats; or short, as in the Land Tortoises. They may be very imperfectly developed, as in Birds.

They may be so united by dense tissue as to be quite incapable of separate motion, as in the Cetaceans. The

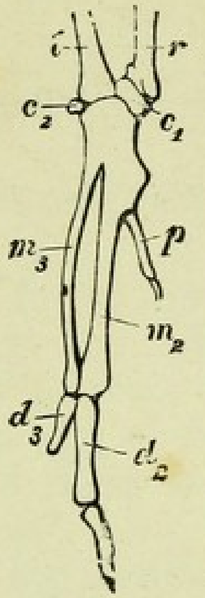

FIG. 149.—RIGHT HAND OF OSTRICH.

c^1, radial carpal ossicle; c^2, ulnar carpal ossicle; d^2, proximal phalanx of the index digit which has three phalanges; d^3, phalanx of third digit; *l*, ulna; m^2 and m^3, metacarpals of second and third digits anchylosed together and with that of the pollex; *p*, proximal phalanx of pollex; *r*, radius.

bones of the fingers or *phalanges* of man are the same in number as in other Mammals with the exception of the Cetacea. In distinctness they also agree with most, but it is possible for the proximal row of phalanges to become anchylosed to the metacarpals, as is the case in the Three-toed Sloth.

The phalanges, instead of decreasing in length, distad,[1] as in man, may so increase—as in the three ulnar digits of *Dasypus villosus.* A terminal phalanx of a digit may far exceed in length its two proximal phalanges, as is the case in the middle finger of *Priodontes*, and in the three middle digits of *Perameles.*

The number of phalanges may be much greater than in man, *e.g.* as many as fourteen, in the third digit of Globiocephalus. Often in Reptiles the number of phalanges increases from two in the pollex to five in the fourth digit, as in the Monitor. The abortive hand of Birds at its best has but

[1] As we proceed from above downwards to the fingers' ends.

three digits, with two phalanges to the pollex, three to the index, and one or two to the third digit.

The terminal phalanges may bifurcate slightly, as in *Perameles* and in the Mole, or widely, as in some Toads and Frogs.

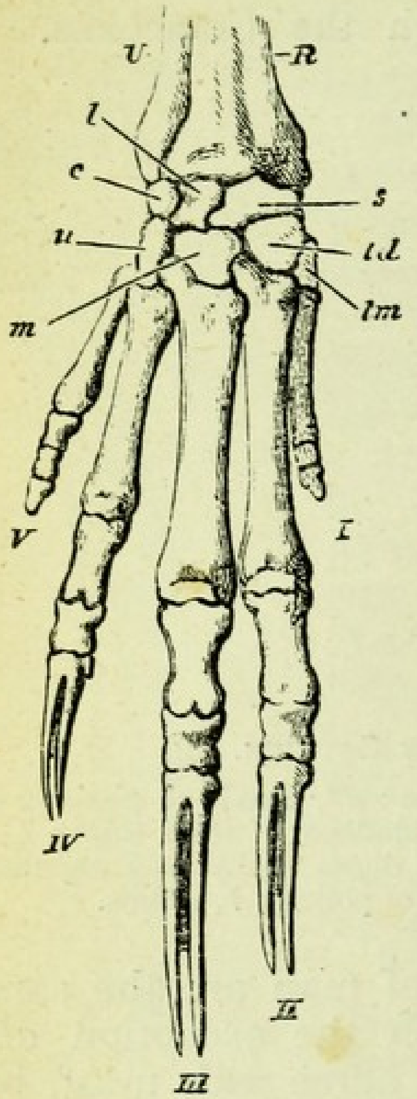

FIG. 150.—BONES OF MANUS OF BANDICOOT (*Perameles*).

c, cuneiforme ; *l*, lunare ; *m*, magnum ; *R*, radius ; *s*, scaphoides ; *td*, trapezoides ; *tm*, trapezium ; *U*, ulna ; *u*, unciforme ; *I.—V.*, the digits ; *I*, pollex ; *V*, little finger.

(*From Flower's "Osteology."*)

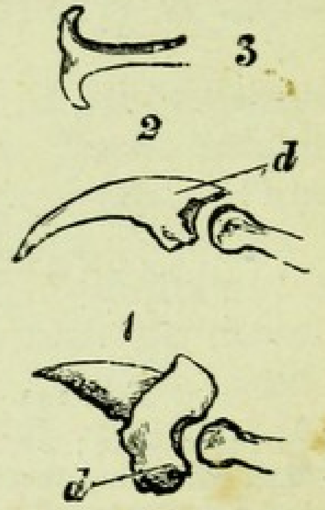

FIG. 151.

1. Ungual Phalanx of a Bear, showing the enlargement at the ventral side of its proximal end, *d*.
2. Ungual phalanx of a Sloth, showing the enlargement, *d*, on the dorsal side of its proximal end.
3. Widely bifurcating distal phalanx of the Toad, *Hylædactylus* (or *Kaloula*).

They may develop a large fold of bone to support the claw, as in the Cats, where the inferior part of their proximal end is much enlarged, while it may be the upper part of the same which is enlarged, as in some Edentates.

LESSON V.

THE SKELETON OF THE LOWER LIMB.

1. THE skeleton of the lower limbs, like that of the upper, is divisible into three categories : A, that of the hip ; B, that of the leg ; and C, that of the foot.

A. The skeleton of the hip, or the haunch-bone, is called the *os innominatum*,[1] and there is one such on each side in the adult man.

B. The skeleton of the leg is subdivisible into—

(*a*) That of the thigh, which consists but of one bone, called the *femur* (*os femoris*).

(*b*) That of the lower part of the leg, which consists of two bones placed side by side. The larger of these is called the *tibia* ; the other, much more slender and placed on the outer side of the leg, is called the *fibula*, or peroneal[2] bone of the leg.

C. The skeleton of the foot is subdivisible into three parts : (*a*) that of the ankle, the *tarsus* ;[3] (*b*) that of the middle part of the foot, the *metatarsus* ; and (*c*) that of the toes, or digits—composed of the *phalanges*.

2. The OS INNOMINATUM is a very large bone, meeting with its fellow of the other side in the mid-ventral line of the body, and being strongly attached to the sacrum behind , thus forming, with the intervention of the last-named bone, a solid bony girdle, supporting the trunk above, and being itself imposed on the limbs below—the head of the thigh-bone fitting into a socket on the outer side of the os innominatum.

Each os innominatum is made up originally of three distinct bones, which become united when youth is merging into manhood. These three bones are the ilium, the ischium, and the pubis.

[1] From its not bearing any special resemblance to any one object.
[2] So called because it clasps the larger bone of the leg, περόνη, a clasp.
[3] From ταρσός, a crate.

The innominate bone thus consists of three parts. (1) A widely expanded upper part joins the sacrum and extends down to the socket for the thigh. This is the ilium.[1]

(2) From the thigh-socket a bar of bone runs forwards and inwards. This is the pubis.[2]

(3) Another, stouter, piece of bone curves first downwards from the thigh-socket, and then inwards and then upwards till it meets the pubis. This is the ischium.[3]

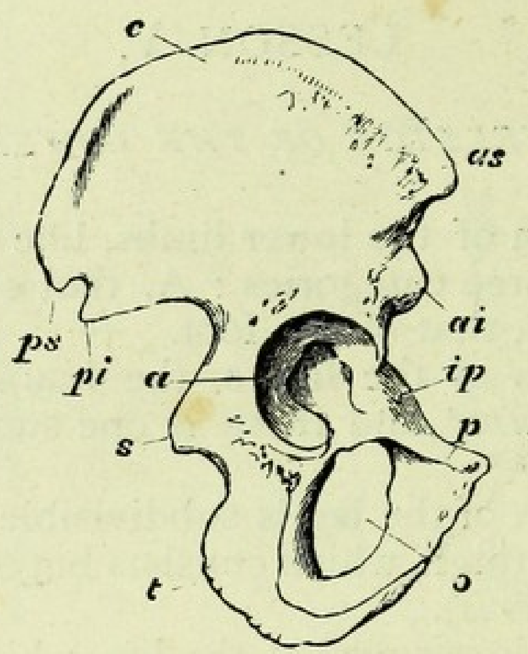

FIG. 152.—OUTER SIDE OF RIGHT OS INNOMINATUM OF MAN.

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 eminence; *o*, obturator foramen; *p*, pubis—its horizontal ramus; *pi*, posterior inferior spinous process; *ps*, posterior superior spinous process; *s*, spine of the ischium; *t*, tuberosity of the ischium.

The *ilium* has a wide outer surface (marked by two curved lines), the upper border of which is termed the "*crest*" and is convex and arched. From the front end of the crest the *anterior* border descends sharply to the pubis, a blunt prominence (called the *ilio-pectineal* eminence) marking the point of junction. A sharp prominence (termed the *anterior superior spinous process*) projects from the anterior border of the ilium at its summit, and another—the *anterior inferior spinous process*—projects from it a little above the thigh-socket. From the hinder end of the crest of the ilium descends its posterior border, the summit of which is marked by the *posterior superior spinous process*, separated by a small notch from a

[1] So called from its relation to the *ilia*, entrails.
[2] In reference to its superficial exoskeleton—*i.e.* the hair.
[3] Named from the Greek ἰσχία, hips.

strongly marked prominence called the *posterior inferior spinous process*, beneath which the border is deeply excavated and concave.

The inner surface of the ilium is concave, forming the *iliac fossa*, and at its hinder part is a rough irregular space for articulation with the sacrum. The ilium forms about the upper third of the socket for the thigh-bone.

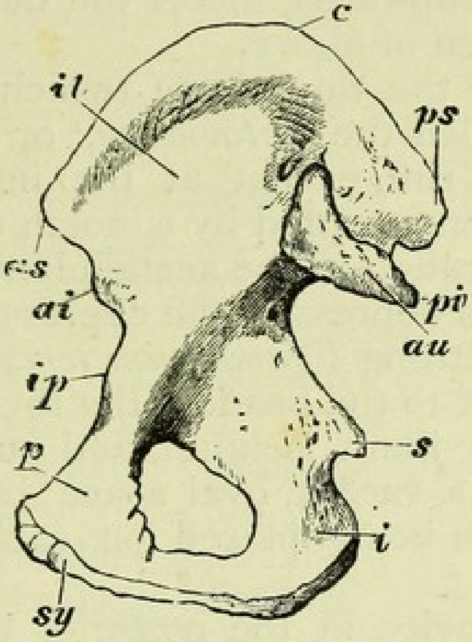

FIG. 153.—INNER SIDE OF RIGHT OS INNOMINATUM OF MAN.
ai, anterior inferior spinous process; *as*, anterior superior spinous process; *au*, auricular surface; *c*, crest; *i*, ischium; *il*, iliac fossa; *p*, pubis—its horizontal ramus; *pi*, posterior inferior spinous process; *ps*, posterior superior spinous process; *s*, spine of the ischium; *sy*, part of the pubis which abuts against its fellow of the opposite side to form the pubic symphysis.

The *pubis*, or pubic bone, forms the inner part of the thigh-socket, joining the ilium above, and at its junction contributing to form the ilio-pectineal eminence. It thence proceeds horizontally inwards (as a band of bone flattened from without inwards, called the horizontal ramus) till it meets with its fellow of the opposite side, when it turns sharply downwards. The junction of the two pubes is termed the *symphysis*, and the part of each pubis next the symphysis is sometimes called the *body*; thence the pubis runs outwards and downwards (as a flattened band, similar to the horizontal ramus, with which it forms an acute angle) till it meets the ascending ramus of the ischium.

The *ischium* forms the outer and lower part of the thigh-socket, and indeed of the whole os innominatum. The *body* of the ischium forms about two-fifths of the socket for the thigh, which cavity is situated on its outer side. The body is broad, and sends from its posterior outer margin a large sharp process called the *spine* of the ischium. Below this, and below the socket, the bone contracts and then expands again, the expansion having a rough prominent surface, which is called the *tuberosity* of the ischium; and it is the two tuberosities (of the two ossa innominata) which support the body when in a sitting posture. Just below the tuberosity, the ischium sends forth a flat band of bone (the ascending ramus), which, curving forwards and upwards, meets the descending bony band of the pubis spoken of above.

The socket for the thigh-bone (which has been so often referred to) is called the *acetabulum*,[1] or *cotyloid*[2] cavity. It has a prominent rim, except at the inner and lower part where the rim is interrupted by a notch (the cotyloid notch). There is no perforation in the acetabulum, but its surface just within the notch is depressed, the depression affording attachment to the very strong *ligamentum teres* (or round ligament) which goes from it to the head of the thigh-bone.

Enclosed by the ilium, ischium, and pubis, there is in each os innominatum a vacant, oval space called the *obturator*[3] *foramen*, one such being placed on each side of the pubic symphysis.

The deep concavity, in the posterior border, between the posterior inferior spinous process of the ilium and the spine of the ischium, is called the *greater ischiatic notch;* the smaller concavity, between the spine of the ischium and the tuberosity of that bone, is called the *lesser ischiatic notch.*

The two ossa innominata, together with the sacrum, form what is called the *pelvis,* or basin-shaped cavity which supports the viscera.

The internal surface of each os innominatum is divided into two parts by a prominent line running upwards and backwards from the upper part of the pubis to the sacrum.

The width from side to side of the pelvis is but rarely exceeded by its depth from behind forwards, but exceeds the greatest vertical extent of the ossa innominata.

A strong ligament connects the tuberosity of the ischium with the sacrum, the coccyx, and the posterior margin of the ilium. This is called the *great sacro-sciatic ligament.* Another ligament goes from the sacrum and coccyx to the spine of the ischium. This is termed the *small sacro-sciatic ligament.*

[1] From its resemblance to an ancient vinegar cup.

[2] From κοτυλη, a cup.

[3] Because it surrounds the obturator membrane which closes up part of the pelvic cavity.

3. The FEMUR is the longest bone of man's skeleton, and, like the humerus, is more or less cylindrical, with a rounded head to fit into the acetabulum above, and with an expansion below with two articular surfaces.

The shaft is slightly arched forwards, is smooth in front but with an elongated prominence behind, termed the *linea aspera*, which is most marked about half-way up the bone.

At the upper end of the shaft are two conspicuous projections. The external one of these (projecting from the outer margin of the bone, which it continues upwards), is called the *great*, or *peroneal*[1] *trochanter*. The internal projection, which is smaller, more conical, and rounded, stands out from the inner and hinder side of the bone, and is called the *lesser*, or *tibial trochanter*.

Between the two trochanters, on the hinder side of the femur, a bony prominence extends, which is termed the *posterior inter-trochanteric ridge;* and a less marked line, the *anterior inter-trochanteric ridge*, also connects the two trochanters on the front surface of the femur.

On the inner and hinder side of the great trochanter is a pit, termed the *trochanteric fossa*.

From the inter-trochanteric ridges a narrower rounded portion of bone projects inwards, forming an obtuse angle with the shaft. This is called the *neck of the femur*. It ends in a rounded *head* (forming a large part of a sphere) which fits into the acetabulum.

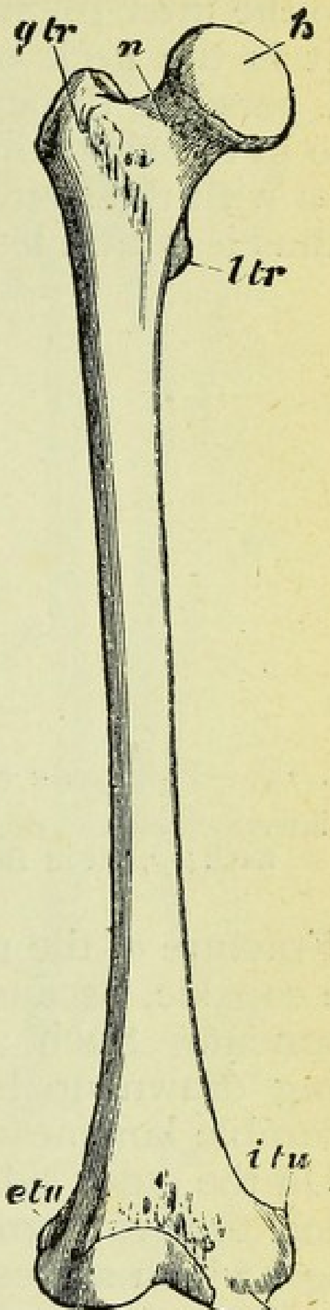

FIG. 154.—FRONT VIEW OF RIGHT FEMUR OF MAN.

ec, internal condyle; *e tu*, external tuberosity; *g tr*, great trochanter; *h*, head; *ic*, external condyle; *i tu*, internal tuberosity; *l tr*, lesser trochanter; *n*, neck of the femur.

The femur is connected with the os innominatum by the strong *ligamentum teres* before mentioned, the attachment of

[1] Because situate on the same side as the peroneal bone of the leg.

which to the femur is indicated by a pit on the head of that bone. It is also attached by a bag-like (or *capsular*) ligament, which, extending from the innominate bone, is inserted into the inter-trochanteric lines.

It is the neck of the femur which is so often broken by old persons, through alteration, not only in the texture, but also in the shape of the bone; for with age the neck comes to form with the shaft a less and less open angle, and the bone is thus less and less adapted to resist vertical pressure.

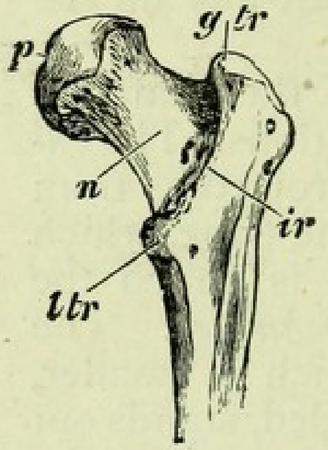

Fig. 155.—Posterior Surface of Upper Part of Right Femur of Man. *ir*, intertrochanteric ridge; *g tr*, great trochanter; *l tr*, lesser trochanter; *n*, neck; *p*, pit in the head of the femur for the *ligamentum teres*.

Fracture of the neck of the bone is called a fracture within the capsule, because the part broken is within the capsular ligament. Such a fracture can never be adjusted, the leg being drawn up by the muscles and shortened, producing incurable lameness for the rest of life.

On the outer side of the hinder part of the femur, a little below the great trochanter, is a more or less marked vertical ridge, which serves for the insertion of the glutens maximus muscle.

At the lower end of the femur are two prominences named *condyles* (see Fig. 154), separated behind by a median depression.

The *external* condyle is the larger, and more forwardly projecting; its articulating surface is also broader and ascends higher on the front of the bone. On its outer surface is a pit for the tendon of the popliteus muscle, immediately above which is a projection named the *external tuberosity*.

The *internal* condyle is longer, and descends lower down than the external one. On its inner side is a projection called the *internal tuberosity*.

The articular surfaces of the femur meet in front, and form one for the knee-pan. Posteriorly they diverge, leaving between them a space called the *inter-condyloid fossa*. The femur does not articulate with the fibula.

The knee-pan, or PATELLA, is a small bone somewhat triangular, yet rounded in outline, convex in front and with two articular surfaces (to fit to the condyles of the femur) behind.

It is attached above by its broad upper margin to the tendon of the front muscle of the thigh. Below, a ligament goes from its pointed lower end to the upper part of the shin-bone.

4. The TIBIA, or shin-bone, is, like the femur, an elongated bone, more so than any other in the human body except the femur. It transmits the whole weight of the body to the foot.

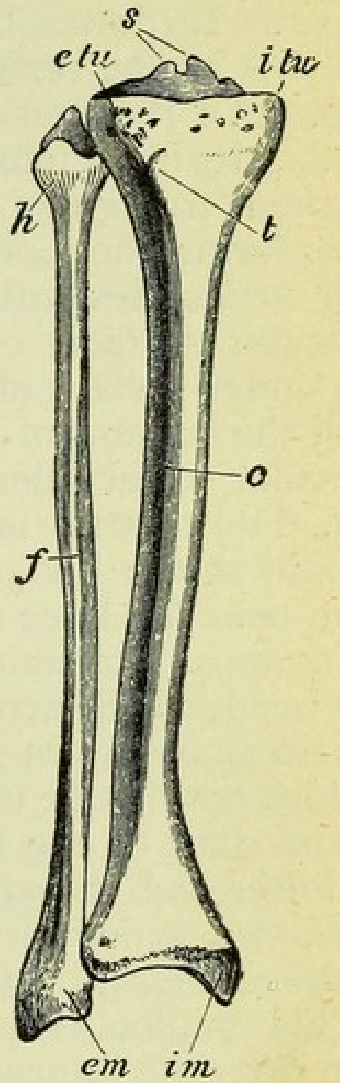

FIG. 156.—FRONT VIEW OF RIGHT TIBIA AND FIBULA OF MAN.

c, crest of the tibia ; *em*, external malleolus ; *e tu*, external tuberosity ; *f*, fibula; *h*, head of the fibula ; *im*, internal malleolus ; *i tu*, internal tuberosity ; *s*, spine of the tibia ; *t*, tubercle.

Its upper end is very wide, and presents two concave articular surfaces (*condyles*)—which receive the two condyles of the femur—and between them an eminence (the spine), behind which is a pit giving insertion to one end of one of the *crucial ligaments* which connect the femur with the tibia. These ligaments pass, one from the pit just mentioned to the outer side of the inner condyle of the femur, while the other goes from the front of the spine of the tibia to the inner side of the outer condyle of the femur. Two inter-articular cartilages, called *semilunar*, are also interposed between the cartilaginous articular surfaces of the femur and those of the tibia.

Two other ligaments may be noted. One, the *internal lateral ligament*, goes from the internal tuberosity of the femur to the inner surface of the tibia ; and the other, the *external lateral ligament*, goes from the outer tuberosity of the femur to the fibula.

The shaft of the tibia is triangular in section, being produced into a sharp *crest* in front, on the internal side of which crest the bone is convex, and concave on its outer side. At the upper end of the front of the shaft is a prominence called the tuberosity, or *tubercle.*

The lower end of the bone is much smaller than the upper. Its lower border has a single groove behind for the tendons of the tibialis posticus and flexor longus digitorum muscles. Its outer surface is concave for the reception of the fibula. Its inner margin is produced downwards into a strongly marked triangular process, called the *internal malleolus.* This forms the bony projection on the inside of the ankle, and articulates with the inner side of the tarsus. Another articular surface, concave and quadrilateral, is situated on the under-surface of the lower end of the tibia, and articulates with the summit of the tarsus. The hinder margin of this articular surface descends below its anterior border.

5. The FIBULA is the slenderest bone, in proportion to its length, in the body, and extends on the outer side of the leg from near the knee down to the ankle.

Its upper extremity is slightly enlarged into what is called the head, which articulates with the outer side of the head of the tibia, and gives insertion to the external lateral ligament. It does not mount upwards so high as does the tibia.

The shaft of the bone is irregularly triangular in section. Its lower end is expanded into what is called the *external malleolus*, which forms the bony projection on the outer side of the ankle and articulates with the outer side of the tarsus.

This malleolus projects downwards considerably further than does the internal malleolus. On its inner side it articulates with the tibia.

Thus we have in man a horizontal articular surface for the tarsus, formed by the lower end of the tibia, and two other articular surfaces, at right angles with it, formed by the surfaces of the malleoli.

6. The TARSUS consists of seven bones (none of which can be called "long bones"), namely, the astragalus, calcaneum, cuboides, naviculare, and three cuneiform bones. All these are so firmly connected by ligamentous fibres which envelop them, that very little mobility is possible, though there may be a slight rotation of the distal tarsal bones upon the proximal ones, that is, upon the astragalus and calcaneum.

The movement of the foot on the leg, however, takes place entirely by the hinge-like joint by which the tarsus articulates with the bones of the leg.

The *astragalus*[1] receives the weight of the trunk from the tibia, and is a short irregularly shaped bone, with a "body, neck, and head."

In its natural position, when the foot is on the ground, the upper surface of the body of the astragalus is nearly horizontal for articulation with the under surface of the shaft of the tibia. Two other articular surfaces, almost at right angles with the former, join the two malleoli respectively. The pos-

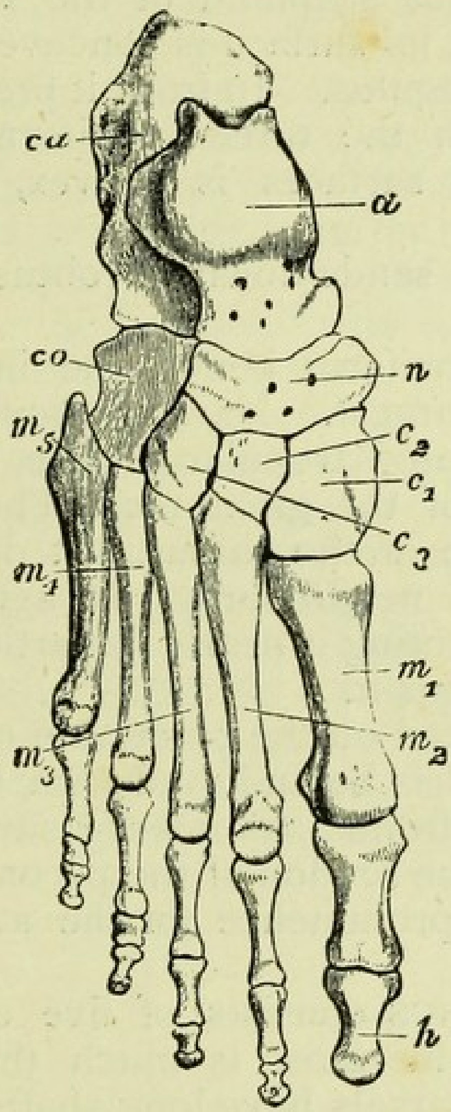

FIG. 157.—DORSUM, OR UPPER SURFACE, OF SKELETON OF RIGHT FOOT.

a, astragalus ; c^1, ento-cuneiforme ; c^2, meso-cuneiforme ; c^3, ecto-cuneiforme ; *ca*, calcaneum ; *co*, cuboides ; *h*, distal phalanx of hallux ; m^1, metatarsal of hallux ; m^2—m^5, metatarsals of the four outer toes ; *n*, naviculare.

terior surface of the body is grooved for the tendon of the flexor longus pollicis muscle. The anterior part of the bone is prolonged forwards as its neck, ending in a rounded, convex, articular surface (the head), which fits into the hinder surface of the naviculare.

[1] Ἀστράγαλος, a die.

The *calcaneum* (or *os calcis*) is the bone of the heel, and forms the posterior part of the arch of the foot, of which the astragalus forms the keystone. The os calcis projects much downwards posteriorly, but not inwards, and is thick and rounded at its hinder end (called its tuberosity), into which is inserted the *tendo Achillis* of the muscles of the calf. The calcaneum articulates with the astragalus above and with the cuboides in front.

The *naviculare* (or scaphoid of the foot) is much wider than long. Behind, its surface is concave for the reception of the head of the astragalus. In front it presents three surfaces for articulation with the three cuneiform bones. Only the innermost of these surfaces is convex, and that but very slightly.

Its inner margin sends down an obtuse process, called its tuberosity.

Of the three cuneiform bones, the innermost, the *ento-cuneiforme*,[1] is the largest. Narrow above and broad below, it presents an elongated articular surface, which is nearly flat, for the metatarsal of the great toe. The *meso-cuneiforme*[2] is the smallest bone of the tarsus. It does not reach so far forwards as do its neighbours. It agrees with the *ecto-cuneiforme*[3] in presenting a nearly flat articular surface for the metatarsal which joins it.

The *cuboides*, placed on the outer side of the tarsus, articulates with the os calcis behind, and with both the fourth and fifth metatarsals in front. Its inferior surface is traversed by a deep groove (for the tendon of the peroneus longus muscle), behind which is a prominence for the attachment of a ligament.

7. The METATARSUS consists of five elongated bones, of which the first or innermost is much the thickest and the shortest. The metatarsals have long shafts, which, except that of the first, are slender, and have enlarged bases and rounded heads.

The bases, or tarsal ends, of the four outer metatarsals have quadrangular articular surfaces, which are almost flat, and are as if bevelled off, so that the axis of each such metatarsal is not perpendicular to its proximal articular surface. Thus these metatarsals come to be directed more inwardly than would otherwise be the case.

The rounded heads of the metatarsals articulate with the hinder concavities of the proximal phalanges.

[1] 'Εντός, inward. [2] From μέσος, middle. [3] 'Εκτός, without.

The first metatarsal has its proximal, concave, articular surface at right angles with the axis of its shaft.

The second metatarsal is the longest.

The fifth metatarsal has its base greatly enlarged, with a considerable prominence, or "tuberosity," projecting from the outer side of its hinder end.

8. The PHALANGES are three in number in each digit, except the first, or great toe (hallux), which has but two. These two, however, are much larger than those of the other toes.

Often the second and third phalanges of the fifth digit (or little toe) become anchylosed together.

The second phalanges are much shorter than the first, and the third phalanges are slightly shorter than the second.

Each last phalanx has its end modified to support a nail, much as we saw in the last phalanges of the hand.

The toes being so much shorter than the fingers, the phalanges are of course also much shorter.

9. Comparing now the relations presented by OTHER ANIMALS, we find that man follows a rule which is universal in having the leg-bones attached to and suspended from a pelvis (well developed or rudimentary), which may be looked upon as the root-portion of the limb. This root part may, however, be present while the distal part (leg and foot) is more or less atrophied, but the distal parts are never present without a rudiment of the limb-root.

The bones of the inferior extremity of man are of full

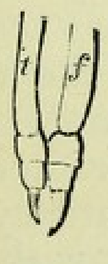

FIG. 158.– RUDIMENTARY PELVIC EXTREMITY OF *Ophiodes*.

(*After Fürbringer.*)

f, fibula ; *t*, tibia.

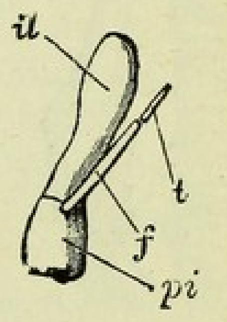

FIG. 159.—SKELETON OF RUDIMENTARY PELVIC LIMB OF *Lialis*.

(*After Fürbringer.*)

f, femur ; *il*, ilium ; *pi*, pubo-ischium ; *t*, tibia.

average development, for though in a few animals these bones may be a little more numerous, in a far greater number of instances the difference from man consists in more or less defect down to complete abortion. A pelvic pair of limbs may be developed without any thoracic ones, as in *Bipes*, *Lialis*, and *Ophiodes*, and rudiments of the pelvic limbs may be the only ones present, as in *Python*.

10. The INNOMINATE BONE of man is one of the most distinctive of his skeleton, distinguishable at a glance from that of every other animal, widely differing even from that of the Gorilla, which, however, much exceeds it in absolute size.

This large complex ossification, consisting as it does in man of three primitive elements, presents three distinct bones in lower animals—the ilium, ischium, and pubis—which, as in man, meet to form the acetabulum.

The fusion of these elements into this one bone is a character which man shares not only with his own class, but also with Birds. In Reptiles, however, we find three permanently distinct bones, whether or not they exactly correspond with the three elements of the pelvis of man.

The fusion of the two ossa innominata in a *dorsal* symphysis is a condition which sometimes occurs—as in the Ostrich. In that his ossa innominata are solidly attached to the vertebral column, man agrees with all Vertebrates above Fishes, with the exception of Cetaceans and some Lizards. In Fishes, however, such a union is invariably absent, and the ossa innominata are represented in them by ventral hard parts only.

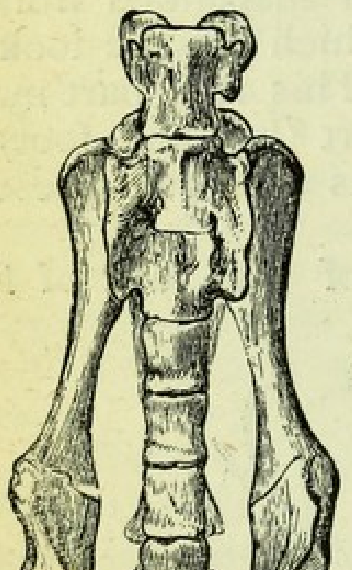

FIG. 160.—Pelvis of the small Tanrec (*Hemicentetes*), showing the very elongated ilia and the widely open pubic symphysis.

The junction of the two ossa innominata at a ventral symphysis is a less constant character. Not only is this junction entirely absent in the class of Birds, with two exceptions (the Ostrich and the Rhea), but in many Mammals (*e.g.* many Bats, and Insectivora).

The ventral union of the ossa innominata with a simultaneous detachment from the vertebral column exists in Fishes, but in no other Vertebrates, unless in some Reptiles with a rudimentary pelvic structure.

A detachment both from the vertebral column dorsally and from its fellow of the opposite side ventrally, is a condition which may occur, as *e.g.* in the very imperfectly developed os innominatum of Cetaceans and Sirenia, and certain Reptiles, *e.g.* the Boa Constrictor.

In that the os innominatum joins the backbone by one attachment only (namely, that of the ilium), man agrees with the great majority of Vertebrates. But even in some of his own class (as in the Armadillos, some other Edentates, and some Bats) a second, ischiatic, bony attachment may be formed, answering to what would result from an ossification of the great sacro-sciatic ligament in us.

As has been said, the form of man's os innominatum is absolutely peculiar. Still he shares the normal characters of his class and of Vertebrates generally, in that the inferior bony elements on each side are rather short and mainly

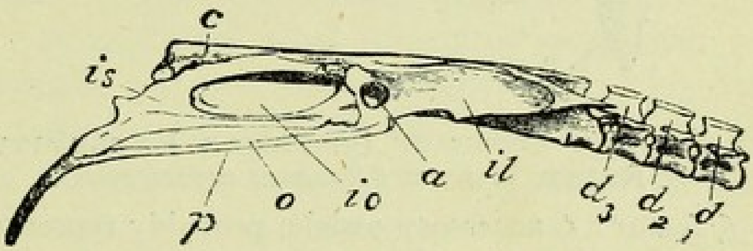

FIG. 161.—RIGHT SIDE OF PELVIS OF A BIRD.

a, acetabulum ; *c*, caudal vertebræ ; d^1—d^3, three dorsal vertebræ ; *il*, ilium ; *io*, great foramen caused by the post-axial union of the ilium and ischium ; *is*, ischium ; *o*, very elongated obturator foramen ; *p*, pubis.

directed ventrally. These elements may, however, be very much elongated and mainly directed post-axially (*i.e.* backwards, if the body is placed horizontally), as in Birds. The ventral elements may be single, as in Batrachians, and if double, as in man, they may apparently consist of parts which do not correspond with the two elements existing in him and other Mammals : such a diversity of structure seems to exist in Reptiles.

In so far as the *ilium* of man is a broad flat bone, it differs from that of Mammals generally, and only agrees with certain exceptional forms, such as the Elephant, Sloth, and Gorilla.

The extent of the ilium in the line of the backbone may be very much greater than in man, as is the case in Birds, where it is prolonged both pre- and post-axially to a very considerable extent, thus connecting in one whole many vertebræ. It is probably the pre-axial part of the bird's ilium which corresponds with that of man and of Mammals, while its post-axial part seems to correspond with the ilium of Reptiles.

The ilium may be a three-sided columnar bone, as in the Kangaroo and many Rodents. The posterior part of the ilium may become anchylosed with the ischium, as is the case in Birds.

Wherever there is an acetabulum it is in part formed by the ilium.

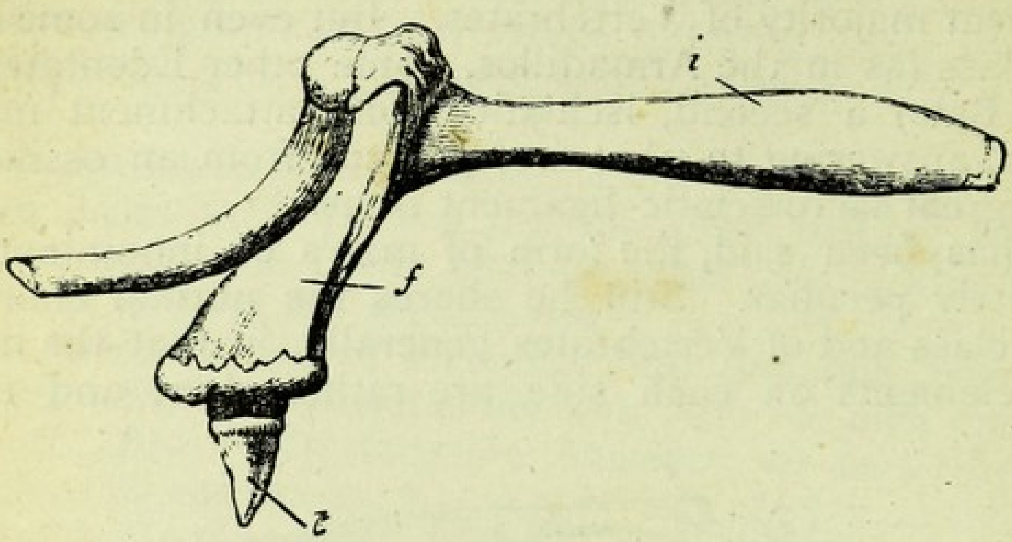

FIG. 162.—SIDE VIEW OF BONES OF POSTERIOR EXTREMITY OF GREENLAND RIGHT WHALE (*Balæna mysticetus*).

i, ischium ; *f*, femur ; *t*, accessory ossicle, probably representing the tibia.

(*From Eschricht and Reinhardt.*)

The ilium may be altogether absent while the ischium is present, as probably in the Cetacea. It is never present without any other pelvic element, except in the Amphisbenian group of Reptiles.

The prominence of the inferior anterior spinous process in man is exceptional, yet it is exceeded in proportion in some of the Lemuroidea.

In Marsupial Mammals and Monotremes we find two distinct bones articulated, one on each side of the pre-axial margin of the pubes. They are called "*Marsupial bones*," and are further noticed below, § 11.

The ilio-pectineal eminence is rudimentary in man compared with that existing in some other animals even of his own class. Thus in certain Bats it is a very elongated spine projecting upwards from the brim of the pelvis, and it is a very prominent process in the Kangaroo, and sometimes in Marsupials arises from an independent ossific centre. In Reptiles we find a pair of separate bones, usually called the pubes, and meeting generally in a ventral symphysis. They do not, however, so meet in all Reptiles, *e.g.* the Crocodiles and the Snake *Stenostoma*. These so-called pubes are at their maximum of relative size in the Tortoise, where each develops a large process ending freely, like the ilio-pectineal eminences or marsupial bones of Mammals.

In Tailed-Batrachians the ilia are represented by rib-like bones which articulate each with one or at most with two

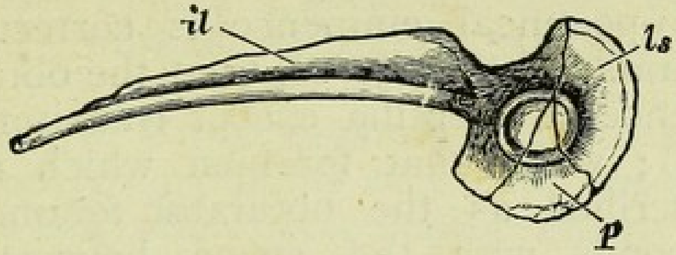

FIG. 163.—RIGHT SIDE OF PELVIS OF FROG.

il, ilium ; *is*, ischium ; *p*, pubis. The three bones meet at the upper margin of the acetabulum.

vertebræ. In the Frogs and Toads the ilia are very peculiar, being extremely elongated, and meeting together posteriorly above the acetabula in an *iliac* symphysis. In spite of the superficial resemblance between the limbs of man and the Frog, the pelvic structures are thus singularly different.

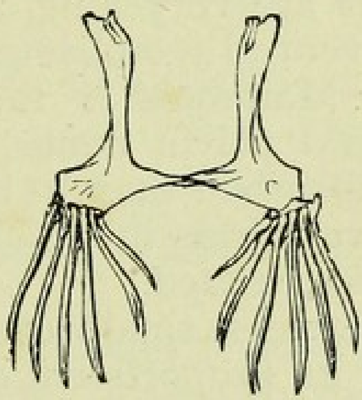

FIG. 164.—The two Ossa Innominata of the Angler-fish (*Lophius*), showing the ascending processes which simulate ilia. The fin-rays are attached to the outer-ventral margin of each os innominatum.

It is not probable that any solid representative of the ilium exists in Fishes, but in the Angler (*Lophius*) the os innominatum sends up a process simulating somewhat the ilium, as does the innominate cartilage in the Chimæra.

The ilium of an animal may closely resemble its scapula in shape, as in the Tortoise and Chameleon.

The so-called *pubis* of Reptiles may answer to the ilio-pectineal eminences, or possibly to the marsupial bones,[1] of Mammals. A small bone attached to the front of the pubis

[1] For these bones see below, p. 194.

of the Ostrich may possibly represent the mammalian marsupial bone.

In that man's pubis is a plainly distinct pelvic element, man agrees with all of his class except those which have an imperfectly developed innominate bone.

In all Reptiles this bone appears (if the view above stated as to the ilio-pectineal eminence is correct) to be fused with the ischium. If this be so, then the obturator foramen has no existence in Reptilia except transitorily (as in the young Lizard); while that foramen which resembles and has been described as the obturator foramen in Reptiles really corresponds with the space between the brim of the pelvis and a line drawn from the marsupial bone, or else from the ilio-pectineal eminence, to the pubic symphysis. This false obturator foramen may be called the *cordiform foramen.*

As has been already said, in some Insectivora and Bats the pubis does not meet its fellow of the opposite side in a ventral symphysis. In the Mole the pubis has so little extent that the pelvic viscera pass outside and in front of the pelvis.

The pubes in Birds are very long, and bent post-axially. They never meet in a ventral symphysis except in the Ostrich.

As the *ischium* in Mammals is the more constant and larger of the two ventral pelvic bones, it may be considered rather itself to have absorbed than to have been absorbed by the pubis, in those lower forms in which these two elements do not seem to be differentiated.

The ischium of man is small compared with that of Mammals generally; its proportional development is closely approached, however, in the slender Loris.

The prominent development of the spine of the ischium is absolutely peculiar to man.

The tuberosity of the ischium in the human species is very small and inconspicuous compared with its condition in most Mammals. Even in the very highest Apes it is much larger than in man, and in the Gibbons and other monkeys of the old world it is not only very large, but everted and flattened with a rough surface for the attachment of a thickened skin, or callosity. It is largely everted in Dogs and Ungulates. In all the Edentates, except the Cape Ant-eater, the ischium anchyloses with the vertebral column, and the same union occurs in some Bats.

In the Cetacea the pelvis is represented by what is probably a pair of ischia. These are long and slender bones detached from each other as well as from the vertebral column.

This ischium may be elongated, produced backwards (*i.e.* post-axially) and downwards, and separated from its fellow in the middle line ventrally, as in all Birds except the Rhea, in which latter these bones bend upwards and meet at their distal ends.

The ischium of Birds generally anchyloses more or less with the posterior part of the very elongated ilium.

In Reptiles the ischio-pubic bone generally meets its fellow in a ventral symphysis. It may do so when the other ventral elements do not so meet. Such is the case, *e.g.*, in the Snake *Stenostoma.* On the contrary, it may fail so to meet its fellow, although the other ventral elements effect a junction. We find this condition, *e.g.*, in the Lizard *Seps.* Often, as *e.g.* in the Boa, the bone may be represented by a mere cartilaginous rudiment.

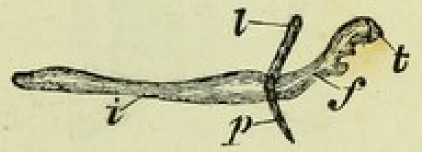

FIG. 165.—SKELETON OF RUDIMENTARY PELVIC LIMB OF BOA CONSTRICTOR. (*After Fürbringer.*)

f, rudimentary femur, at the end of which is (*t*) a minute, triangular, and hook-like tibia; *i*, so-called pubis—possibly an enormous ilio-pectineal eminence; *l*, rudimentary ilium; *p*, ischium or pubo-ischium.

A tuberosity of the ischium generally exists in Lizards; this does not, however, anchylose with the vertebral column, but is connected by a strong ligament with the hinder end of the ilium, which ligament answers to the great sacro-sciatic ligament of man.

In Tailed-Batrachians the ischio-pubic bone or cartilage is a large lamelliform expansion with an elongated symphysis. It may form one single cartilaginous undivided plate, as in *Proteus.* In Frogs and Toads the ischia are small, lamelliform, and so closely applied and anchylosed together as to be, as it were, all symphysis.

In Fishes the ossa innominata have already been noticed, and they consist probably of ischio-pubic bones or cartilages only. We here, however, often meet with an anomaly of connexion not found in any higher class. Thus we find the innominate bones in many cases directly connected with the pectoral girdle. In some Fishes, as *e.g.* the Angler (*Lophius*), the ossa innominata are articulated directly with the hinder border of the clavicles, while in other Fishes they very often are but little removed from them. Fishes in which the hinder limbs are placed far forwards are called *thoracic* (as the Perch), and when still more so, *jugular* (as the Cod).

Rarely, as *e.g.* in the Opah Fish (*Lampris*), the os innominatum joins the coracoid, which in this species is enormously enlarged.

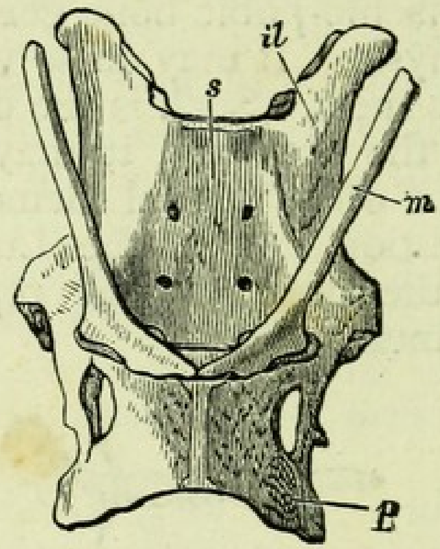

FIG. 166.—PELVIS OF ECHIDNA.

il, ilium ; *m*, marsupial bone ; *p*, pubis ; *s*, sacrum.

11. Certain bones called MARSUPIAL BONES, of which no ossified representatives exist in man, may be attached to the pelvis. Thus, in him the internal tendon of each external oblique muscle is neither ossified nor chondrified. In all Marsupials, however (except the Thylacine, or Tasmanian Wolf), and in the Monotremes, these tendons are largely ossified, the ossifications being movably articulated with the brim of the pelvis. Such ossifications constitute the marsupial bones. In the Tasmanian Wolf these parts are represented by cartilages, but no such structures have been detected in other Mammals, except that there is a slight chondrification of the same part in the Dog. In the Chameleon the brim of the pelvis supports small bony nodules, and in the Ostrich a small bone is attached to the front of the pubis. Possibly (as before said) the so-called pubic bones of Reptiles may be marsupial bones, if they do not rather correspond to ilio-pectineal eminences.

Another possible ossification which has no representative in man is the *os cloacæ*. It is an azygos median structure which extends backwards behind the ischio-pubic symphysis, as *e.g.* in the Lizard *Psammosaurus*.

Similarly a median azygos structure (pointed or forked) may be developed from the front of the ischio-pubic symphysis, as in *Menobranchus* and *Salamandra*.

The *acetabulum* of man is very well developed as compared with that of other animals. In its formation by the three pelvic bones it follows the universal mammalian rule. In that its cup is completely ossified it also resembles all Mammals except the lowest (*i.e.* the Monotremes), which agree with Birds in having the acetabula perforated.

In Reptiles generally three separate ossifications also concur to form the acetabulum. In Crocodiles, however, the so-called pubis does not concur in its formation.

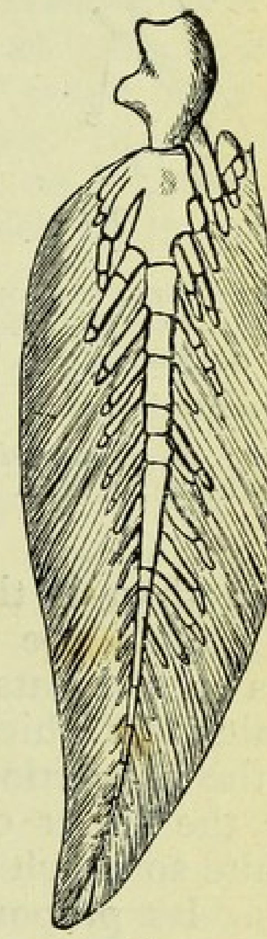

FIG. 167.—CARTILAGINOUS SKELETON OF A LIMB OF *Ceratodus*. (After Günther.)

The large upper piece articulates with the limb root.

12. The supremacy in size of man's FEMUR over the other parts of his skeleton is not shared by the femur of most other Vertebrates, and this important bone seems rarely, if ever, to have any representative whatever in the skeleton of Fishes. Nevertheless a single cartilage (as in *Ceratodus*) which articulates with the limb root may be the representative either of the thigh or leg bones.

Confining ourselves therefore, for purposes of comparison, to Mammals, Sauropsida, and Batrachians, we find the femur under a certain aspect more constantly present than the humerus. For although it is often absent when the humerus is present (as in forms like *Siren*, which have pectoral limbs but no pelvic ones), yet it is sometimes present in a more or less rudimentary condition when no representative of the foot coexists with it.

Such is the case, *e.g.*, in some Whales (as the Greenland Whale) amongst Mammals, and certain Snakes, e.g. *Boa*, and certain Lizards, e.g. *Lialis*, amongst the Reptiles. In absolute length the femur of man exceeds that of almost all other animals, only the largest beasts forming an exception in this respect.

As the longest bone of the leg (*i.e.* in the proportion in which it exceeds the length of the tibia) the femur of man is distinguished from that of all Birds, and from that of almost all other Mammals except of those Cetaceans which have a rudimentary femur and a still more rudimentary tibia. Yet occasionally (as *e.g.* in the Great Ant-eater and certain Apes) the femur notably exceeds the tibia in length.

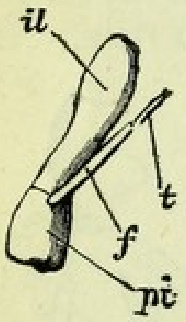

Fig. 168.—Skeleton of Rudimentary Pelvic Limb of *Lialis*.

(*After Fürbringer.*)

f. femur; *il*, ilium; *pi*, pubo-ischium; *t*, tibia.

In many Reptiles and Tailed-Batrachians, however, the femur exceeds the tibia as much as or more than in man, and that not only in forms like *Boa*, where both bones are, though in different degrees, rudimentary, but also where both are fairly developed.

For all that the several parts of the femur may exhibit different degrees of development in different animals, yet on the whole it is a substantially constant bone as to its form and structure; more so even than is the case with the humerus, as the femur never attains the great relative length which the humerus attains in the Bats, nor is it ever reduced to the shortness and thickness which that part presents in the Mole.

In the proportion which it bears to the hind limb as a whole, the femur of man is exceptionally developed, though not quite so much so as in many Reptiles and Tailed-Batrachians. Its proportion, however, may become almost insignificant, even in Mammals, as in the Seals. It is in these aquatic Carnivora, and in the extinct Ichthyosaurus, that the femur is relatively at its shortest.

It is a short bone (when compared with the leg and foot) in the Ruminants and Horse family.

The curvature which the shaft presents in man may be exaggerated, as in Tortoises, while the bone may almost become straight, as in the Lemurs, Carnivora, Bats, &c.

The development of its neck is a character which the femur of man by no means shares with that of all Vertebrates; on the contrary, the neck of the bone is most exceptionally developed in him. In the majority of cases (as *e.g.* in Birds) there can hardly be said to be any neck, and in many forms, *e.g.* the Rhinoceros, there is none whatever.

The head of the femur is almost always rounded; rarely (as *e.g.* in the Crocodile) it is transversely extended, somewhat like that of the humerus in Birds.

The greater (peroneal) and lesser (tibial) trochanters are very constant structures, one or both appearing in a more or less developed condition down to the lowest Batrachians.

The great trochanter may be more prominent than in man. This is the case, *e.g.*, in Ungulates. It may, on the contrary, be comparatively insignificant, as in the Great Ant-eater and Elephant; or absent, as in the Lizard *Grammatophora.*

The lesser trochanter may be about as salient as the greater one, as in the Ornithorhynchus; or much more so, as in *Uromastix*, *Leiocephalus*, and *Cyclodus;* it may be all but absent, as in the Elephant, or quite so, as in Birds.

The two trochanters may be equally developed, one on each side of a very short neck, as in Bats.

The two trochanters may be fused into one, as in *Testudo.*

In addition to the two trochanters, the slight ridge which serves in man for the insertion of the glutens maximus muscle may be drawn out into a great prominence termed a "third trochanter." This is the case, *e.g.*, in the Horse, Rhinoceros, Hare, and Armadillos.

This third trochanter may be represented by a prominent ridge running along the whole outer side of the shaft, as in the Great Ant-eater.

The head of the femur, instead of being directed inwards, may project forwards over the exterior surface of the bone, as in *Testudo* and the Bats.

The pit for the ligamentum teres, though present in Birds, may be quite absent in members of man's own class, *e.g.* in Seals, Elephants, Sloths, and others. This depression, apparently so important, may be present or absent in different individuals of the same species, as in the Orang-Outan and Gorilla.

The lower end of the femur may be more, or less, expanded relatively than in man, and this both transversely and antero-posteriorly.

Thus the latter dimension is greatly in excess in the Ruminants; the transverse dimension in the Seals and Ornithorhynchus.

Instead of the inner condyle descending the more, it may be the outer one that does so, as is the case in Birds.

The depression in front between the condyles—"*rotular* surface"—(serving in man to lodge the patella) may be wanting, as in *Testudo*, or all but wanting, as in the Wombat. It may be very narrow, as in *Pteropus.* It may be much marked, as in the Ruminants.

The pit for the origin of the popliteus muscle may be much deeper, and coexist with a similar pit in the external condyle (for the origin of the flexor longus digitorum muscle), which condition, together with the narrowness of the rotular surface, may give the lower end of the femur a peculiar aspect, as in *Pteropus.*

The external condyle may present a marked groove subdividing it. This is the case in Birds, where this groove serves to receive the head of the fibula.

Instead of the concavity which exists in man at the postero-inferior part of the shaft (increased through the backward projecting of the condyles), this part may be nearly flat, as in Birds.

Neither tuberosity is ever perforated like the internal condyle of the humerus in some Mammals.

The femur may be only a rudiment even in some Mammals,

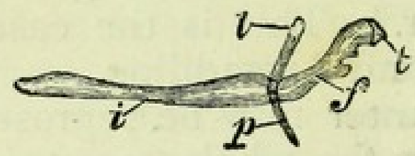

FIG. 169.—SKELETON OF RUDIMENTARY PELVIC LIMB OF BOA CONSTRICTOR. (*After Fürbringer.*)

f, rudimentary femur, at the end of which is (*t*) a minute, triangular, and hook-like tibia ; *i*, so-called pubis—possibly an enormous ilio-pectineal eminence ; *l*, rudimentary ilium ; *p*, ischium, or pubo-ischium.

as *e.g.* some fin Whales ; and the same may be the case in some Reptiles, as e.g. *Lialis Burtonii*, *Boa*, and *Stenostoma.*

The PATELLA may be wanting altogether in man's own class, as in the Wombat. It may be very small, as in the Bats and Seals. It may be very narrow in proportion to its length, as in the Agouti ; or extraordinarily large and elongated, as in the Grebe ; or represented by two super-imposed ossifications, as in the Ostrich. Every trace of it may be wanting, as in the Frogs and Tortoises. It may be irregular in shape, as in the Bustard and Ostrich.

13. That important bone of man, the TIBIA, attains a yet greater relative size in very many Vertebrates than it does in him. Like the femur, however, it is not universally present in every class, as it has no distinct representative in Fishes.

As compared with its fellow leg-bone (the fibula), the tibia shows a predominance of size, like that of the radius in the arm over the ulna, and this to a yet greater degree. Thus while, like the radius, it never aborts though its fellow may do so, it never in existing animals even becomes the subordinate bone of the two, as is the case in the radius compared with the ulna in Birds. Yet in length it may be exceeded by the fibula, as *e.g.* in the Ornithorhynchus; and a certain slight subordination appears to have existed in the extinct Reptiles *Ichthyosaurus* and *Plesiosaurus*. Moreover, the two bones are developed equally in certain existing Reptiles with rudimentary limbs, e.g. *Seps* and *Ophiodes*, and in Batrachians also.

In its elongated figure the tibia of man agrees with the same bone as generally developed, and it never becomes in any existing species so relatively short and thick above as does the radius in Cetacea. Such is the case only in the extinct Plesiosaurus and Ichthyosaurus.

The relation which it bears to the femur is less constant than that which the radius bears to the humerus. We have seen that where in Vertebrates above Fishes the humerus is

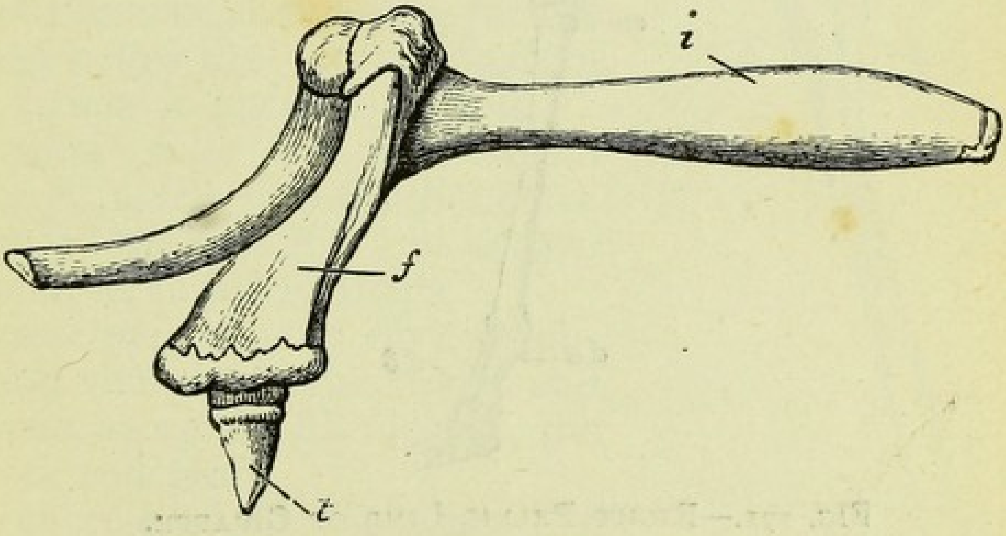

FIG. 170.—SIDE VIEW OF BONES OF POSTERIOR EXTREMITY OF GREENLAND RIGHT WHALE (*Balæna mysticetus*).

i, ischium ; *f*, femur ; *t*, accessory ossicle, probably representing the tibia.

(*From Eschricht and Reinhardt.*)

represented by a bone or cartilage, the radius is also developed. But in *Megaptera longimana* and *Balænoptera musculus* we have a rudimentary representative of the femur, but none whatever of the tibia ; while in *Balæna mysticetus* and in *Boa constrictor* there is a tolerably large ossicle representing the femur, but only a minute rudiment representing the tibia.

Instead of being free as in man, the tibia may anchylose at each end with the corresponding extremities of the fibula, as is the case in the Armadillos and often in the Seals.

Very often it anchyloses with the fibula below only, as in the Rabbit and in some Birds, *e.g.* Adjutant and Ostrich (and as in one member of man's own order, *Tarsius*) ; or above only, as, at least sometimes, in the Cape Ant-eater.

There may be an apparently single representative of the two bones of the leg which are completely fused together, as in the Frog.

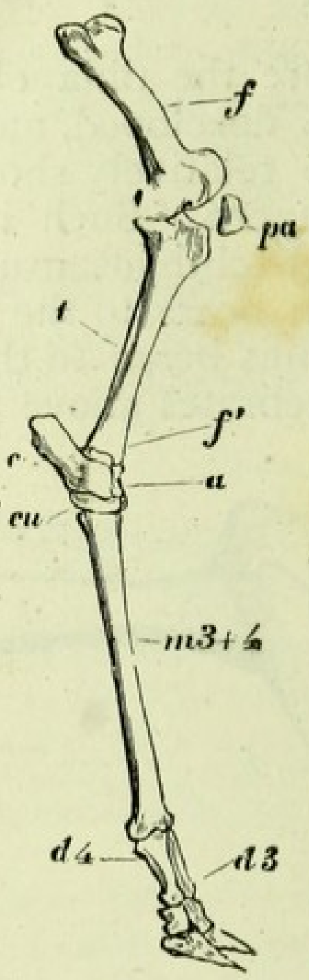

FIG. 171.—RIGHT PELVIC LIMB OF GIRAFFE.

a, astragalus ; *c*, calcaneum ; *cu*, cuboides ; d^3, proximal phalanx of third digit ; d^4, proximal phalanx of fourth digit ; *f*, femur ; *f′*, rudiments of fibula (the line is not continued far enough—the rudimentary fibula is a small ossicle reposing on the upper surface of the calcaneum, as shown in the figure): m^{3+4}, metatarsals of digits 3 and 4 united into one "cannon-bone" ; *pa*, patella ; *t*, tibia.

The tibia may be the only long bone of the leg, through the small development of the fibula, as is the case in Ruminants and in the Horse tribe.

The space which exists in man between the tibia and the fibula may be exceedingly reduced, as is the case, *e.g.*, in Birds and in some Mammals, *e.g.* the Cats. It may, however, be very wide, as in the Sloths and Wombat and Cape Ant-eater.

This bone in man is peculiarly shaped in relation to his erect posture.

Thus, comparing man's tibia with the same bone in other members of his own order (Primates), we find that it is longer as compared with the spine than in any other genus except *Hylobates* and *Tarsius*, and longer as compared with the radius than in any except *Hapale* and *Tarsius*.

On the contrary, its length as compared with the femur is less than in any other Primate.

The tubercle of the tibia is probably at its maximum of distinctness in man as compared with the rest of his class, and the articular surfaces for the condyles of the femur occupy a maximum proportion of the upper surface of the tibia.

The sharpness of its crest in man exceeds that of any other Primate, and the descent of the posterior border of the articular surface for the astragalus below the anterior margin of that surface is peculiar to him.

The tibia may be very much curved, *e.g.* in the Ornithorhynchus, yet it may be straight and excessively long, as in many Birds.

The crest may project very prominently and sharply at the upper end of the bone, as *e.g.* in Ruminants, the Kangaroo, and Hare.

The tubercle of the tibia may be enormously produced upwards into a long pointed process, as in certain Birds, *e.g.* the Grebe and Divers.

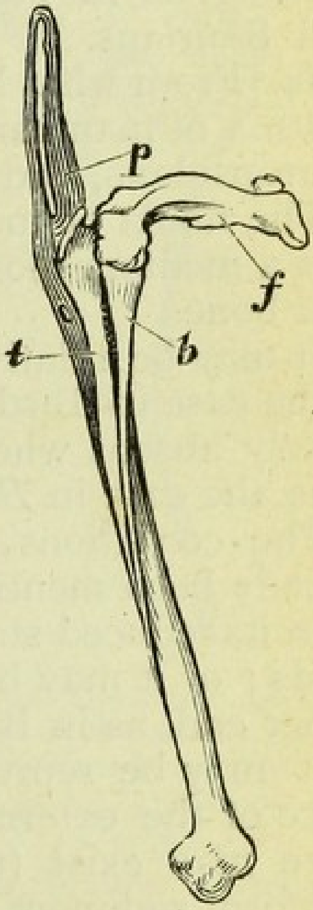

FIG. 172.—LEG-BONES OF THE DIVER (*Colymbus*).

b, fibula ; *f*, femur ; *t*, tibia, with *p*, its enormously produced tubercle.

In some forms nearly allied to man, as the Orang, the articular surface of the malleolus forms an obtuse angle with the inferior surface of the tibia.

The tibialis posticus groove may be much deeper than in man, the portion of bone separating it from that for the flexor longus pollicis pedis having thus the appearance of a prominent process. Such is the case in *Nycticebus*.

Distinct malleoli may be wanting, and are so in Vertebrates below Mammals. The lower end of the tibia of all adult Birds is very different from that of the other classes. This, however, is due to its being made up of the proximal part of the tarsal element, on which account it cannot here be compared with the lower end of the tibia of man and Mammals. Nevertheless, exceptional forms (like the Ostrich) show us that the true tibia of Birds is destitute of malleoli.

The tibia never assumes that crossed position in relation to the fibula which the radius assumes in relation to the ulna, and which is termed pronation. Nevertheless, a modified action may take place in certain Marsupials, viz. the Phalangers and Wombat.

Crucial ligaments and inter-articular cartilages may be wanting, as in Tailed-Batrachians, though present in Birds and Saurians.

14. From what has been already said it is clear that the FIBULA of man can only be illustrated by bones of Mammals, Sauropsidans, and Batrachians.

The fibula of man in its subordination to the tibia, occupies a medium position, as has been noticed in describing that bone.

It may be relatively more reduced in size than in man, as is the case in Birds and in Ruminants; or it may be completely absent when the tibia is rudimentarily represented, as is the case in *Balæna mysticetus* and *Boa constrictor*.

The conditions as to its anchylosis with the tibia have already been mentioned.

In its reduced state the fibula may be quite styliform, as in Birds; or it may be developed inferiorly, but atrophied at its upper end, as in Bats.

It may be represented only by a small ossification in the place of the external malleolus, as in the Ox, and with this there may exist (though widely separated from it) a little styliform rudiment of the upper end of the fibula, as in the Elk.

The fibula may be much bowed outwards, as in the Chameleon and the Bat *Molossus*, but it is generally nearly straight, or quite so, as in Birds.

The upper end of the bone may join the femur, as in Marsupials and Birds, and this end may be produced into a large process like the olecranon of the ulna (as in Cook's Phalanger), to which even a sesamoid bone may be annexed.

This process may attain a very great size, as *e.g.* in the *Ornithorhynchus* and *Echidna*.

In man alone does the external malleolus descend greatly below the internal malleolus. The lower end of the fibula may be very much enlarged, as in the Hippopotamus. Its lower end may develop a conical process, which, turning inwards, may fit into a depression on the outer side of the articular surface of the astragalus, as in the Sloth.

15. Inasmuch as the FOOT of man is made up of the tarsus, metatarsus, and phalanges, it agrees with the same part in Mammals and Batrachians.

In Birds, however, the proximal part of the tarsus is anchylosed with, and in Reptiles more or less firmly united with, the tibia, so that the visible foot of Birds corresponds but with the greater portion and not the whole of the foot of man.

The foot, in one aspect, is less constant than the hand, as elements of the leg (as in *Balæna* and *Boa*) may be present while there is no rudiment whatever of the foot.

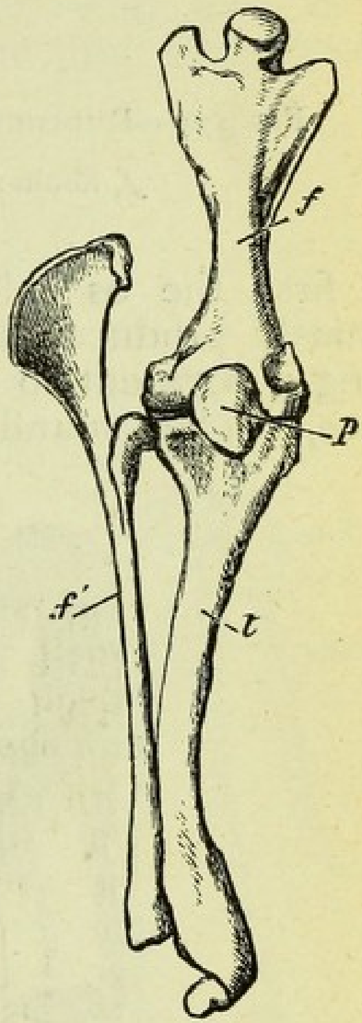

FIG. 173.—ANTERIOR ASPECT OF BONES OF RIGHT LEG OF *Ornithorhynchus paradoxus*.

f, femur; *t*, tibia; *f'*, fibula; *p*, patella.

(*From Flower's "Osteology."*)

16. In that the TARSUS of man contains certain small and distinct bones, it agrees with the same part in all Vertebrates above Fishes, except Birds (in which the tarsus coalesces with other portions of the skeleton), and except also certain Tailed-Batrachians, in which the constituent parts of the tarsus remain more or less permanently cartilaginous.

The number of ossicles, or cartilages, may be as many as nine, as in the Salamander; or may be reduced to three, as in *Proteus*, *Bufo bifurcatus*, and *Lacerta agilis;* or perhaps to two, in *Ophiodes striatus*.

We have seen that part of the carpus of man may be represented by more elongated bones, as in the Crocodile.

This variation may, however, be carried out to a much greater degree, and in two different ways, as regards the tarsus.

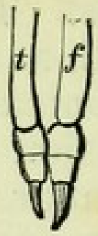

FIG. 174.—RUDIMENTARY PELVIC EXTREMITY OF *Ophiodes.*
f, fibula ; *t*, tibia. (*After Fürbringer.*)

For, first, the os calcis and naviculare may be so extraordinarily produced as to become completely long bones—adding a segment to the limb—as in *Tarsius*, and, in a less degree, in *Galago* and *Cheirogaleus*.

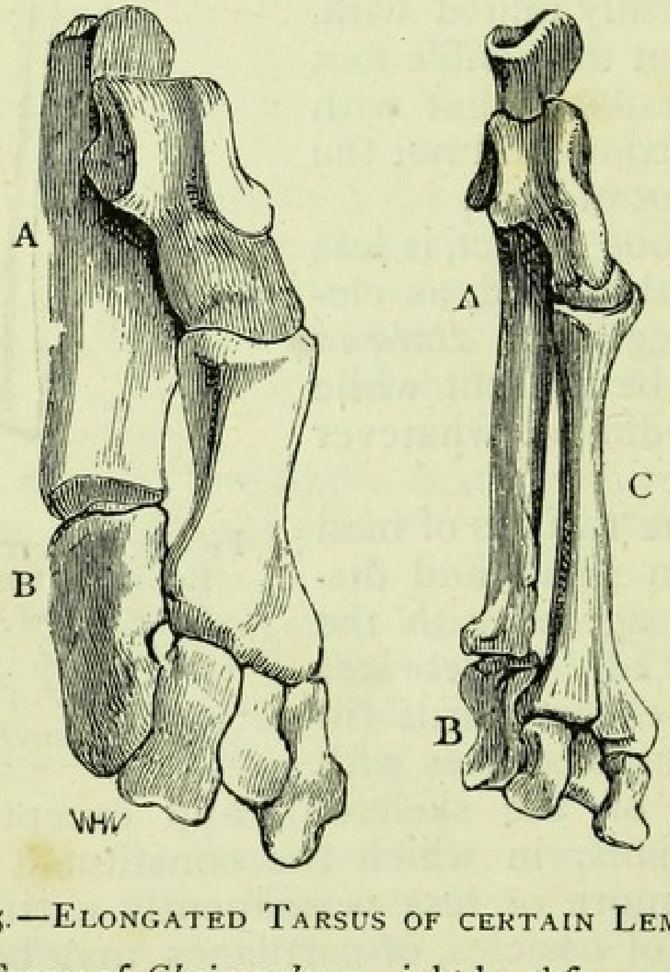

FIG. 175.—ELONGATED TARSUS OF CERTAIN LEMUROIDS.
Left-hand figure, Tarsus of *Cheirogaleus* ; right-hand figure, Tarsus of *Tarsius.*
A, calcaneum ; *B*, cuboides ; *C*, naviculare.

Secondly, the os calcis and astragalus may be similarly elongated, as in the Frogs.

17. The BONES OF THE PROXIMAL PART OF THE TARSUS are always the largest and most important.

The *astragalus* and *os calcis*, and probably also the *naviculare*, may be represented by a single bone, as in many Lizards, and they may intimately fuse at an early age with the distal end of the tibia, as in almost all Birds.

In this latter case these bones unite very early into one, which remains long distinct from the tibia, only in the Ostrich, Rhea, and Emeu; and for some time after hatching in the Dorking Fowl.

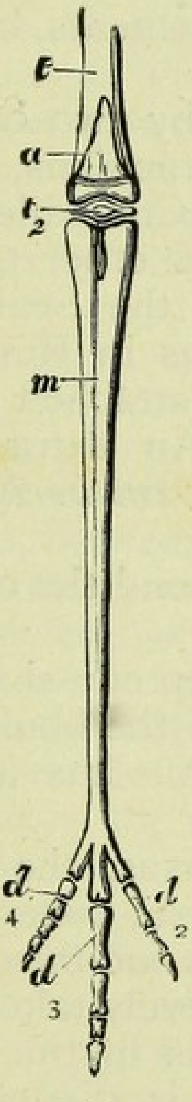

FIG. 176.—RIGHT FOOT OF EMEU.

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.

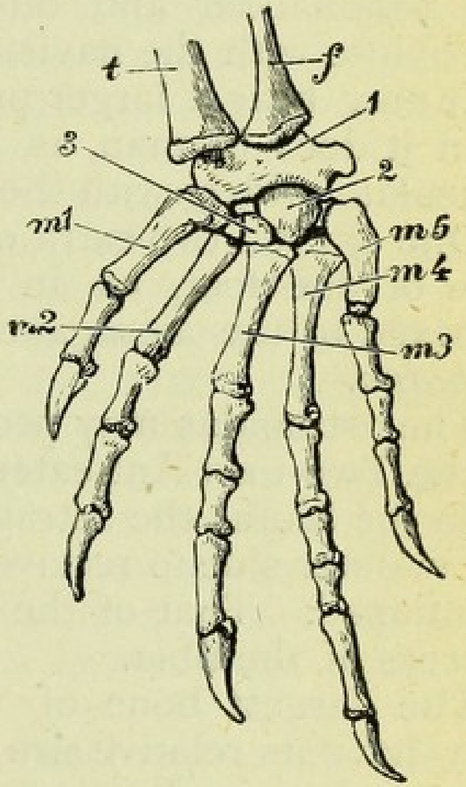

FIG. 177.—LEFT FOOT OF A MONITOR LIZARD (*Varanus*).

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.

In Lizards this compound bone is extended transversely, but very little backwards. It articulates with both the tibia and fibula above, and has an irregular surface below for the reception of the more distal tarsal bones.

In Birds it is also transversely and but little antero-posteriorly extended, while it sends up a process which is applied to the front of the tibia (Fig. 176, *a*). It may be perforated by one or two canals for extensor tendons of muscles.

Thus no projection corresponding with the tuberosity of the os calcis exists in this compound bone.

Inasmuch as the *astragalus* of man articulates with the tibia, it has a character which is constant. A distinctness like that which it possesses in him is not only, as we have seen, far from universal, but its distinctness is less than that of its serial homologue in the hand ; for not only may the astragalus anchylose with other tarsal elements, but with the long bone of the limb also, as in Birds.

The astragalus may be represented by two bones, as in the Salamander and other Tailed-Batrachians, or it may anchylose with the naviculare, as in the Crocodile.

It may bear a larger proportion to the other tarsal bones than it does in man, as is the case in the Seals. It may articulate widely with the cuboid bone, as in Ruminants.

One or even two extra ossicles may be attached to the tibial side of the foot, as in *Cercolabes.* An extra ossicle is annexed to the astragalus in the male *Ornithorhynchus* and *Echidna.*

The astragalus may project much beyond the os calcis, as in the Two-toed Ant-eater.

In the Sloths the astragalus has a deep cup-shaped cavity on its outer side to receive the process of the fibula, as before mentioned. That of the Ornithorhynchus has a cup for a process of the tibia.

The largest bone of the human tarsus, the *calcaneum,* may have its relative size to the other tarsal bones yet further increased, as in *Tarsius,* where it attains one-third the length of the spine from atlas to sacrum inclusively taken. It may, on the contrary, be much diminished, as in the true Seals, or still more so, as in Birds. Where it is distinctly ossified in Tailed-Batrachians and Reptiles, it develops no tuberosity, except in the Crocodiles, where that process is still small. In Birds this bone seems very early to be absorbed into the astragalus.

It never seems to anchylose with any other tarsal element, unless it also anchyloses with the astragalus, as in Birds and in many Reptiles, e.g. *Lacerta agilis.*

The tuberosity may be very much twisted in man's own order, e.g. *Perodicticus* and *Loris.* It may be all but absent, as in the Seals. It may be, on the contrary, enormously produced, as in the Horse.

It may have appended to it an elongated ossification which in parts enters upon the tendo Achillis, as in Bats, and this may be of great breadth as well as length, as in *Noctilio leporinus.*

The end of the os calcis is broad, bifid, and incurved in the *Ornithorhynchus* and *Echidna.*

In that man's ankle-joint is situated between the leg-bones and the tarsus, it agrees with the same part not only in the whole of his own class, but also in Batrachians. It may be, however, that the joint by which the foot moves upon the leg is not so situated. This is the case in all Birds, where motion takes place not between the tarsus and the tibia, but between the proximal and the distal parts of the tarsus, the ankle-joint being in them an inter-tarsal one, with the proximal part of the tarsus anchylosed to the tibia, and its distal part to the metatarsus.

A similar joint exists in Crocodiles, though the proximal part of the tarsus is firmly attached to the leg-bones but by fibrous tissue, and not by anchylosis.

Much more mobility than obtains in man may exist even in Mammals, between the proximal and distal parts of the tarsus, as in the Orang, and especially in Galago.

The leg, instead of being set on the foot vertically, as in man, may be applied obliquely, as *e.g.* in the Orang and Potto.

There was, doubtless, in the Ichthyosaurus a limitation of motion between the bones of the hind limb, similar to that which we find in the existing Cetacea between the bones of the fore limbs.

The *naviculare*, or *scaphoid*, may anchylose with one of the distal row of tarsal bones, as in the Ox and Deer, where it unites with the cuboid.

Instead of being situate as in man, it may be central and distinct, as in Salamandra and other Tailed-Batrachians, and as in *Chelydra* and *Chameleo.* It may be very short and very wide transversely, as in the Horse.

Its tuberosity may be much produced, as in *Hylobates.* The articular surfaces for the cuneiforme may be remarkably convex, as in *Loris.*

The naviculare may be greatly produced, as is the case in *Galago* and *Tarsius.*

18. The BONES OF THE SECOND ROW are far less constant and never so large and conspicuous as are those of the

first row. They may coalesce with the metatarsals, as is the case in Birds, the Chameleon, and in *Bradypus*. Almost always short, these bones may yet, as in the Insectivore *Rhynchocyon*, be lengthened somewhat, while the proximal bones are not so.

The *ento-cuneiforme* presents characters which differ interestingly from man's, in species which are closely allied to him. Thus the articular surface for the first metatarsal, instead of being flat, as in him, becomes convex even in the Gorilla, and completely saddle-shaped in the Lemurs, as also in the prehensile-footed Marsupials, *e.g.* the Phalangers.

A strong tubercle may project from the middle of the inferior margin of the tibial surface, as in *Lemur*.

The ento-cuneiforme is much the largest of the three cuneiform bones in the Seals, but it may be quite wanting, as in the Ox and Sheep.

It may coalesce with the meso-cuneiforme bone, as in the Horse and in *Hyla palmata*, or with the ento-cuneiforme also, as in the *Alligator lucius*.

The *meso-cuneiforme*, instead of being as in man, may be relatively very much smaller than the other cuneiforms, as in the Armadillos called Encoubert and Cabassou, but it is never very much larger.

It may anchylose with the second metatarsal, as in the Chameleon and *Bradypus*.

As has been said, it may coalesce with one or both of the other cuneiforms in certain Reptiles.

The *ecto-cuneiforme* may enormously preponderate over the other cuneiforms, as in the Horse. It may, on the contrary, be decidedly smaller than the ento-cuneiforme, as in the Seals.

It may coalesce with the third metatarsal, as in Birds, the Chameleon, and *Bradypus*; with both the other cuneiforms, as in *Alligator lucius*; or with the meso-cuneiforme only, as in *Rana esculenta*. It may be the only distinct representative of the cuneiforms, as in *Bufo bifurcatus*.

This and the meso-cuneiforme may be the largest bones of the tarsus, as in *Pygopus lepidopus*.

The single condition in which the *cuboides* exists in man is universal in his class, unless sometimes in the Ornithorhynchus, where it is said to be represented by two bones, as is certainly the case in some Batrachians, *e.g.* in *Salamandra* and the Axolotl.

It may, however, coalesce with the naviculare, as in the Ox and Deer.

It may unite with the fourth and fifth metatarsals, as in the *Chameleo* and *Bradypus*.

19. The distinctness of the METATARSUS and the development which this segment of the limb attains in man are

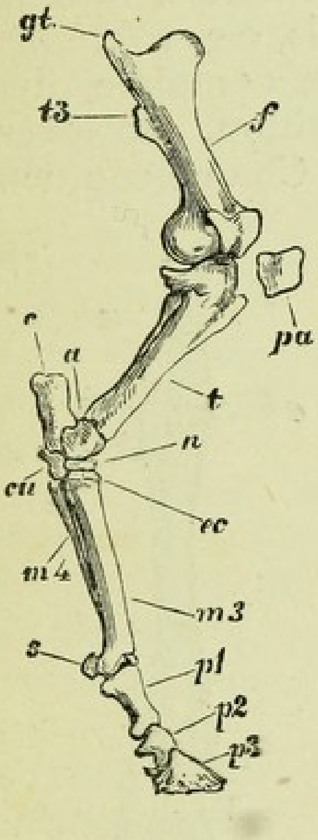

FIG. 178.—SKELETON OF RIGHT PELVIC LIMB OF HORSE.

a, astragalus ; *c*, calcaneum ; *cu*, cuboides ; *ec*, ecto-cuneiforme ; *f*, femur ; *gt*, great trochanter ; m^3, metatarsal of third digit ; m^4, rudimentary fourth metatarsal ; *n*, naviculare ; *pa*, patella ; p^1, p^2, and p^3, first, second, and third phalanges of the third and only digit ; *s*, sesamoid ; *t*, tibia ; t^3, third trochanter.

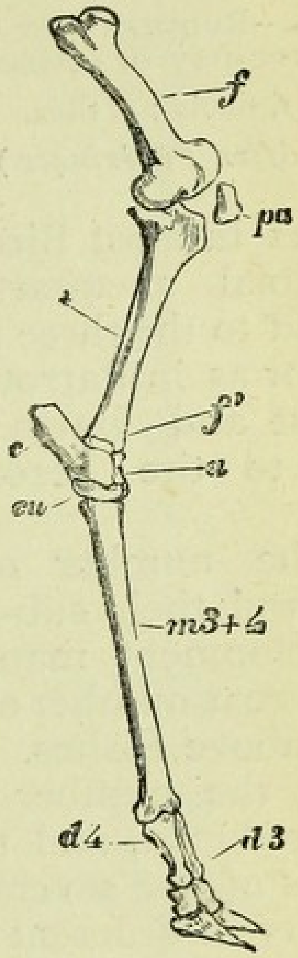

FIG. 179.—RIGHT PELVIC LIMB OF GIRAFFE.

a, astragalus ; *c*, calcaneum ; *cu*, cuboides ; d^3, proximal phalanx of third digit ; d^4, proximal phalanx of fourth digit ; *f*, femur ; *f'*, rudiment of fibula (the line is not continued far enough—the rudimentary fibula is a small ossicle reposing on the upper surface of the calcaneum, as shown in the figure) ; m^{3+4}, metatarsals of digits 3 and 4 united into one "cannon-bone" ; *pa*, patella ; *t*, tibia.

characters which are normal in man's class, and more or less so in that of Reptiles. The metatarsus may be of much greater relative length than in man, as is the case in the Ungulata.

It may be that the metatarsals coalesce with the distal part of the tarsus, as in Birds, the Chameleon, and *Bradypus*.

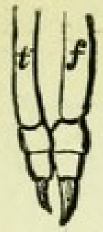

FIG. 180.—RUDIMENTARY PELVIC EXTREMITY OF *Ophiodes*.

f, fibula ; *t*, tibia.

(*After Fürbringer.*)

Metatarsals may coexist each with only one if any phalanx, as in *Ophiodes*. The first metatarsals may widely diverge from the line of the others, as in non-human Primates, and in some Marsupials, e.g. *Phalangista*.

A more complete divergence or opposition, however, may exist, as in most Birds ; or as in the Chameleon, where the two tibial metatarsals are opposed to the three peroneal ones ; or as in Parrots, where the first and fourth are opposed to the second and third.

In the number of these bones and their sub-equality of development man agrees with a great number of Vertebrates above Fishes. Nevertheless, the number may be much reduced, and the proportions of the several bones may vary in different modes.

Thus there may be but a single metatarsal, the third, with rudiments of the second and fourth, as in the Horse ; or but a single large one, the fourth, with the second, third, and fifth metatarsals very small, as in *Chœropus*.

There may be but a single bone, which consists of the third and fourth fused together, as in the Sheep, Deer, &c., and in the Ostrich ; or of second, third, and fourth fused together, as in the Jerboa and the Emeu ; or of these and the first also, as in many Birds.

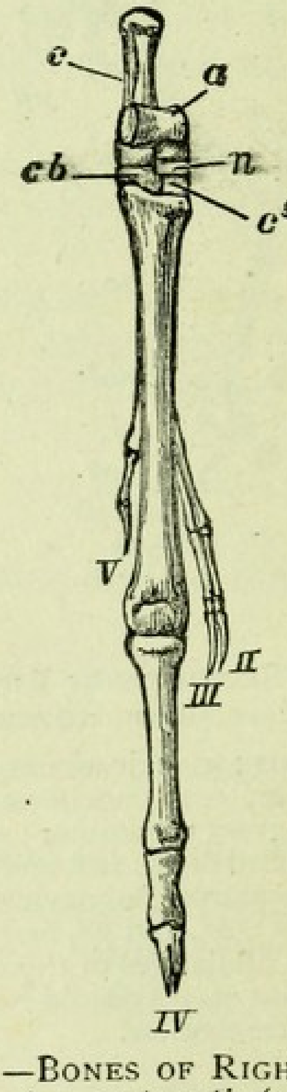

FIG. 181.—BONES OF RIGHT FOOT OF *Chœropus castanotis* (nat. size).

a, astragalus ; *c*, calcaneum ; *cb*, cuboides ; c^3, ecto-cuneiforme ; *n*, naviculare ; *II. III. IV.* and *V.*, second, third, fourth, and fifth digits.

(*From Flower's "Osteology."*)

In such cases a separation of the lower end of the bone into articular condyles for the different digits indicates the composite nature of the bone.

There may be but four metatarsals well developed, as in the Dog; or but three, as in Rhinoceros; or two, as in the Hog and *Proteus*; or but one, as has been mentioned, in the Horse and *Chœropus*.

They may be anchylosed together at their proximal ends, as in the Three-toed Sloth.

The metatarsals never seem to decrease in size from the first to the fifth, but often, as in man, from the second to the fourth. They may increase in size from the first to the fifth, as in the Great Ant-eater and the Ornithorhynchus.

The two central ones may greatly exceed the lateral ones, as in the Hog; or the first and fifth may greatly exceed in size the three central ones, as in the Seal.

The second metatarsal is never exceptionally reduced, while the other four all remain well developed.

The metatarsals are never enormously elongated like the metacarpals of Bats.

All may be extremely short and stunted, as in the Land Tortoises and Ichthyosaurus.

The number five is never increased (except by monstrosity) in any known Vertebrates.

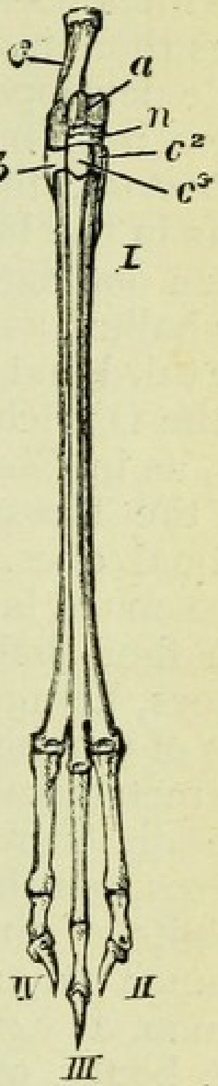

FIG. 182.—BONES OF RIGHT PES OF JERBOA (*Dipus Ægyptius*).

a, astragalus; *c*, calcaneum; *cb*, cuboides; c^2, meso-cuneiforme; c^3, ecto-cuneiforme; *II. III.* and *IV.*, second, third, and fourth digits.

(*From Flower's "Osteology."*)

The vertical line of bilateral symmetry in the foot may pass (as in the Ox and Sheep), so as to have the third metatarsal on one side of it and the fourth metatarsal on the other; or it may (as in the Horse and Rhinoceros) pass through the middle of the third metatarsal.

The latter symmetry may prevail where there are four digits, as in the Tapir; and the former symmetry may prevail where there are but three digits, as in the Peccary.

20. The BONES OF THE TOES. These may be entirely wanting for all that there are metatarsals, as perhaps in *Ophoides*. The number of toes (digits) which may be developed has been indicated in treating of the metatarsus.

Thus there may be but a single digit, as in the Horse, and a single developed one, as in *Chœropus*.

There may be but two, as in the Ox and Sheep, Ostrich and *Proteus;* three, as in the Rhinoceros, Jerboa, and Rhea; four, as in the Hare, Dog, and most Birds.

When one digit is wanting, it may be the fifth, as in Birds, or the hallux, as in the Hare.

The third and fourth digits may be the only functional ones, as in the Ostrich; but the third may abort, leaving only the fourth, as in *Chœropus;* or the fourth, leaving only the third, as in the Horse. The fourth and fifth may be the only functional ones, as in the Kangaroo. The first and fifth may be much larger than the others, as in the Seals.

The first (hallux) may be more or less opposable, as in Monkeys, Lemurs, Opossums, and Phalangers. Other oppositions of the digits may exist, as already noticed in speaking of the metatarsals.

The digits may be excessively stunted, as in the Land Tortoises, but they are never so enormously produced as are the digits of the hands of Bats. They may, however, be very much larger with relation to the tarsus than is the case with man, as *e.g.* in the Orang.

The bones of the toes in man equal in number those developed in other Mammals, except in the Orang, where the second phalanx of the hallux may abort altogether.

In their distinctness these bones also agree with those of most Mammals, but it is possible for the proximal row of phalanges to become anchylosed to the metatarsals, as is the case in the Three-toed Sloth.

In that his phalanges decrease in length distad, man follows the rule of his class generally. But the second phalanges may be much larger than the proximal ones, as in the Two-toed Sloth.

The penultimate phalanx may be considerably larger than the more proximal ones of the same digit, as in the fourth toe of Birds, *e.g.* the Eagle.

The number of phalanges may be different from that in man. They may be much more numerous, as in the extinct Ichthyosaurus and Plesiosaurus, or the numbers of the phalanges as we proceed from the first to the fifth digit may be 2, 3, 4, 5, 4, as in Lizards, or 1, 2, 3, 3, 2, as in Salamandra, or 2, 2, 3, 4, 3, as in the Frog. In Birds (where the fifth digit is never developed) the numbers of the phalanges of the four digits, proceeding from the hallux, are mostly 2, 3, 4, 5; but they may be 2, 3, 3, 3, as in the Swifts, or 2, 3, 4, 3, as in the Goatsuckers. It is by the number of their phalanges (4 and 5) that the two digits of the Ostrich are known to answer to the fourth and fifth digits of other Sauropsidans (*e.g.* Lizards) which have all five digits developed.

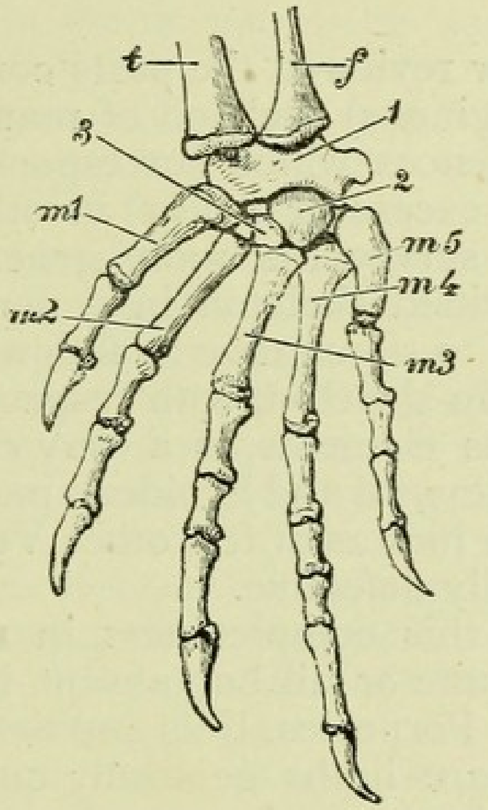

FIG. 183.—LEFT FOOT OF A MONITOR LIZARD (*Varanus*).

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.

The terminal phalanges may bifurcate, as in the short-tailed Pangolin, or develop a fold of bone to support the claw, as in Cats and Edentates, *e.g.* the Sloths.

LESSON VI.

THE INTERNAL SKELETON GENERALLY CONSIDERED.

1. HAVING now reviewed the parts composing the internal (bony and cartilaginous) skeleton of man, and seen the more remarkable differences which corresponding parts may present (whether by excess or defect) in other animals, we are in a position to survey the more general relations of the ossified or chondrified skeleton in general, and that of man in particular, and to summarize as follows :—

The human endo-skeleton, with respect to the number and development of its elements, is a very complete one, except as regards the coccygeal and hyoidean parts of it. The former of these aborts in him as in few other Vertebrates ; the latter is less exceptionally defective.

In contrast to this completeness in man, whole skeletal regions may be quite or all but absent in some other forms, as in Whales and Porpoises, Eels and Serpents. In Serpents, indeed, not only are limbs generally quite wanting, but the hyoidean region aborts much more than it does in man.

Man's endo-skeleton is highly organized with regard to the mutual relation and adaptation of its parts, though, except as to the opposability of the thumb to the fingers, it is not more perfect in this respect than is that of many beasts.

With regard to the number of separate bones of which it is composed, when adult, man's skeleton occupies an intermediate position ; as, though in many Vertebrates (especially Fishes), the actual number is greater, yet some Vertebrates (as Frogs, Tortoises, and most Birds) have a smaller number.

Thus, while more of the bones of the skull, as also of the sacral region, become fused together in him than in most forms, yet a smaller number of such bones escape anchylosis in the class of Birds than in man.

As to the extent of persistent cartilage in the adult condition, man shares, speaking broadly, the characters of his class. Ossification is carried further in the class of Birds, but much less far in Batrachians and Fishes. In some Fishes, indeed (both of the highest and lowest forms), the entire skeleton remains throughout life persistently cartilaginous, while in the lowest form of all Vertebrates (the *Amphioxus* or Lancelet) it is mainly represented by fibrous membrane only.

2. Reviewing the form and development of the spine in man, we may note certain significant facts and generalizations :—

(1) The backbone exhibits to us a good example of serial symmetry. The successive vertebræ are evidently serial repetitions of parts in some sense the same, *i.e.* are serial homologues, or *homotypes*.

(2) We find that modifications may be produced by the suppression in some vertebræ of parts existing in others, as *e.g.* of the neural arch in the coccygeal vertebræ.

(3) We find that modifications may be produced by the coalescence of parts by anchylosis, *e.g.* the anchylosis of the sacral vertebræ to form the sacrum.

(4) Parts bony in one portion of the spine may be represented by membrane only in another, as we see in the neural canal of the sacrum closed in part by membrane only.

(5) A vertebra with annexed parts (two ribs and the intervening piece of the sternum) may completely encircle the body cavity. This suggests the question whether there may not be membranous representatives of ribs similarly enclosing the body cavity, annexed to parts of the spine where there appear to be no bony ribs, as *e.g.* in man's lumbar and cervical regions.

(6) The transverse processes of some at least of the cervical vertebræ arise by separate centres. This suggests the question as to whether their nature may not be essentially different from that of the transverse processes of the dorsal vertebræ.

(7) We have seen that a vertebra may include (besides a centrum and neural arch with its processes) double transverse processes, vertebral and sternal ribs, and a sternal segment ; the whole forming an external or (parietal) ventral arch, while beneath the centrum may be developed a second, deeper, more internal hypapophysial arch.

(8) The varying conditions presented by the two vertebræ next the skull in different animals above Fishes, suggest the question whether we can reduce to a common type that

exceptional structure, the odontoid process of the axis vertebra of man.

3. First, as to the question just suggested regarding man's cervical vertebræ.

It is well known to anthropotomists that the ventral (anterior) root of the transverse process of the seventh cervical vertebra (if not also of vertebræ nearer the head) ossifies separately.

At the same time the dorsal (posterior) root of the same transverse process plainly answers to the whole of the so-called transverse process of a dorsal vertebra, namely, to that part which articulates with the tubercle of the rib. As we have seen, this cervical transverse process may be, in the lowest Mammals and in Crocodiles, a distinct, more or less Y-shaped bone.

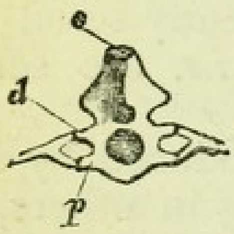

FIG. 184.—Vertebræ of an Axolotl, showing the proximal bifurcation of the rib to meet the superimposed paraxial processes; *d*, tubercular process; *p*, capitular process; *s*, spinous process.

Now, just such a condition of the proximal end of a rib is, as we have seen, well exemplified in many Batrachians (e.g. *Menopoma* and *Menobranchus*), in which a dorsal (tubercular) and a ventral (capitular) transverse process articulate with a Y-shaped rib, one branch being applied to each process.

Thus a Y-shaped bone attached to a cervical vertebra may be interpreted in two ways: (1) as a small rib which has united with it parts of both the "tubercular" and the "capitular" processes of the vertebra to which it is annexed; or (2) as a rib with a "tubercle" so largely developed as to equal the "head and neck" in size.

Plainly, then, the "perforated" transverse processes of man's cervical vertebræ consist, in part, of rudimentary ribs.

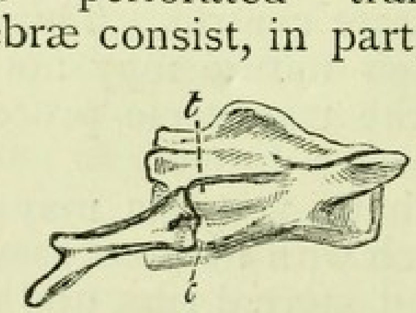

FIG. 185.—LATERAL VIEW OF SIXTH VERTEBRA OF SALAMANDRA.

This figure shows the rib bifurcating not only proximally to meet the super-imposed paraxial processes, *t* and *c* (diapophysis and parapophysis), but also distally.

It was noted that the distal ends of the cervical transverse processes of man diverge as two small processes, termed "tubercles." Now, if each transverse process represents a rib, we have here a slightly bifurcating rib. But this, as we have seen, is a condition which plainly obtains in certain Batrachians, where the rib not only bifurcates proximally, but also distally.

4. Secondly, as to the question above suggested respecting the "odontoid process" in man.

It has been seen how in many animals we have a distinct "odontoid" bone—instead of an odontoid process—interposed between the axis and the atlas; but we have nowhere observed a fully developed centrum of the atlas co-existing with such an odontoid bone.

This fact indicates, what is no doubt the case, that the "odontoid process" is the true centrum of the atlas, united, not with the rest of its own vertebra, but with the centrum of the axis.

What, then, is the nature of that transverse bar of bone belonging to the atlas, and passing, in man, in front of and articulating with the odontoid process? It is probably hypapophysial in its nature, as wedge-like hypapophysial ossicles are often developed between the adjacent margins of vertebræ on their ventral aspect, as *e.g.* beneath the lumbar vertebræ of the Mole. It may, however, be an ossification of part of an intervertebral body.

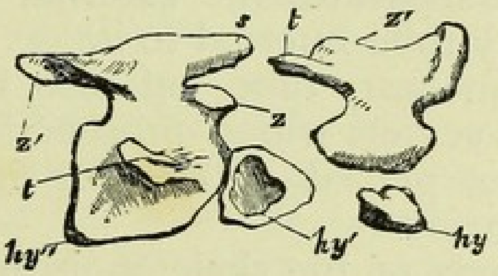

FIG. 186.—ATLAS AND AXIS VERTEBRÆ OF A CHELONIAN REPTILE.

hy, hypapophysis of atlas; *t*, transverse process; *z*, prezygapophysis; *z'*, postzygapophysis; *s*, neural spine; *hy'*, odontoid bone; *hy''*, hypapophysis of true centrum of axis.

(*From the College of Surgeons' Museum.*)

Thus harmony and unity become manifested by means of a general study of anatomy, which would escape us did we investigate the human structure alone.

5. In considering the most general relations of the human skeleton it will be convenient to imagine the backbone placed horizontally, with the limbs descending at right angles from it, such being the position of the backbone in the great majority of Vertebrates.

The fundamental facts of development (noticed in the Second Lesson) must also be borne in mind: how the dorsal laminæ ascend and form the neural canal, and how the ventral laminæ descend to form the trunk. Also, how each of these ventral laminæ splits longitudinally on each side into an outer plate, forming the body-wall (bones, muscles, nerves, &c.), and an inner plate, forming the alimentary canal and its appendages—the split laminæ being united respectively at their ventral ends.

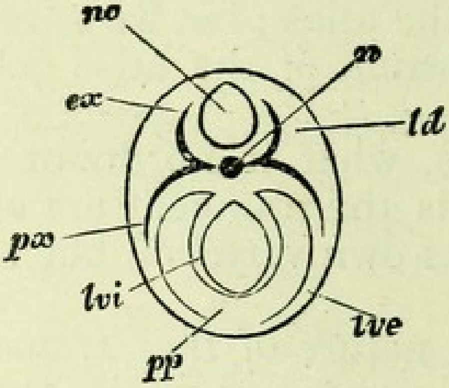

FIG. 187.—Diagram of the development of the Trunk and its Skeleton, as shown in a section made at right angles to the trunk's long axis. *nc*, neural canal; *ex*, epaxial cartilages ascending to surround it; *px*, paraxial cartilages descending in the plate, or layer (*lve*), external to *pp*, the pleuro-peritoneal cavity; *lvi*, internal plate of the split ventral lamina.

Between these outer and inner plates is a space (to be treated of in the Eleventh Lesson) called the pleuro-peritoneal cavity, which thus separates the external tube of the trunk from the alimentary tube internal to it.

Not only the alimentary tube, but also the heart and the roots of the great vessels which proceed from it, are, as we shall hereafter see, placed within the inner wall of this pleuro-peritoneal cavity.

6. The central axis of the skeleton is evidently the notochord with the structures immediately investing it, together with those which generally—by ossification—replace or encroach upon it later in the development of the individual.

In one single form, the Lancelet, and in that only, the notochord extends forwards to the front end of the body, and much beyond the spinal marrow, the anterior end of which is the only representative of the brain. In all other forms the notochord stops short behind the pituitary fossa or the part representing it.

Nevertheless, median parts in the same axial line with the notochord may be formed, as the pre-sphenoid, which is as it were a supplemental piece of the axis added on later to the primitive termination of the skeletal central axis.

Generally the axis of the skeleton (*i.e.* the backbone) consists of a number of segments (vertebræ) which are serially homologous one with another.

7. From this axis we have seen corresponding arches (cartilaginous or osseous) to arise and enclose the spinal marrow, which is the central part of the nervous system of the trunk. They also are serial homologues (homotypes) one of another; and such arches, as they extend above the axis, have been called *epaxial*[1] arches. In man such arches are wanting (as bony structures) in part of the sacral and in the coccygeal regions; yet we have seen how numerous and complete they may be in those regions in other animals.

8. We have seen also that a number of arcs may extend out from the central axis on each side, and that these may descend and meet in the middle line below, so as to form a series of large ventral arches enclosing the body cavity. They also are homotypes one of another; and such arches, as they extend from the sides of the backbone, have been called *paraxial*[2] arches. In man such arches are complete only in the thorax, where the lateral arcs, each composed of a rib and cartilage, are medianly united by the help of the sternum.

It is evident, however, that these arcs may be much more extensively developed in regions where they are wanting in man, as *e.g.* in the cervical vertebræ of the Crocodile, and in the anterior coccygeal vertebræ of some Chelonians and of *Menobranchus*.

9. Each paraxial arc, however, has been seen very generally to have two attachments to the backbone—one above, the other below, *i.e.* one more dorsal than the other.

In man we have the transverse process and tubercle of the rib placed dorsally; and the surface for the head of the rib, the head itself and the neck, more ventrally. In other cases, e.g. *Menobranchus*, we find a distinct dorsal (or tubercular) process, and a more ventral (or capitular) process, giving attachments respectively to the diverging branches of a Y-shaped rib.

Sometimes we have seen the ribs bifurcate distally as well as proximally, as in Salamandra; and sometimes, as in certain Fishes, *e.g.* the Tunny and *Polypterus*, there are two series of ribs on each side, one above the other.

We may thus distinguish two series of paraxial parts on each side, one made up of tubercular processes (or

[1] Ἐπί, upon (the skeletal axis). [2] Παρά, beside (the axis).

diapophyses[1]) and ribs, and the other made up of capitular processes (or parapophyses[2]) and ribs.

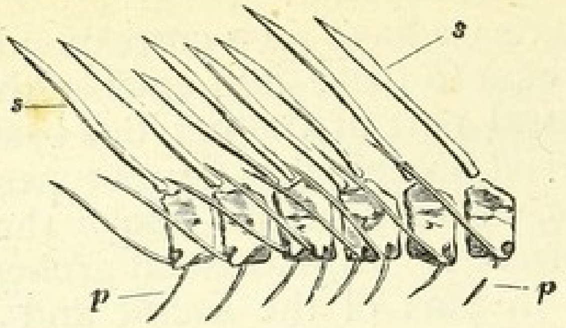

FIG. 188.—SIX TRUNK-VERTEBRÆ OF THE FISH *Polypterus*.

p, series of inferior ribs, from the roots of which the series of superior ribs (*s*) diverges and extends outwards and upwards.

In man, as in most Vertebrates, the superimposed pairs of these two series of parts are completely united, except at their root, but a wider examination shows their probable essential duplicity, and makes visible relations and a significance in the transverse process of his thoracic and cervical vertebræ, which no study of anthropotomy, however patient and minute, could of itself reveal.

10. Still less would it, from such study, be possible to divine the nature of that hardly noticeable ridge which extends along the middle of the body of his axis vertebra on its ventral aspect; yet that ridge is really a rudiment of a system of parts hardly less conspicuous and important in the vertebrate skeleton than the two series already noticed.

It may be remembered, however, that in some Mammals (*e.g.* the Ornithorhynchus) a median spinous process projects downwards from beneath the centrum of the cervical vertebræ; as also the great development of such processes (hypapophyses) in poisonous Serpents, and their extension through the greater part of the whole vertebral column.

We have also seen how such median structures are directly in series with and answer to processes descending in pairs, or to forked processes, which start from a common bony stalk; also that arches (chevron bones) of similar nature may attain a very large size, as in the tails of Whales and Porpoises.

Finally, we have seen that a still more important and conspicuous part may be played by the same skeletal elements, as in some Fishes (*e.g.* the Sole), where elongated arches and

[1] From διά, through. [2] Παρά, beside.

processes of this kind descend from the vertebral centra and constitute a large proportion of the whole axial skeleton.

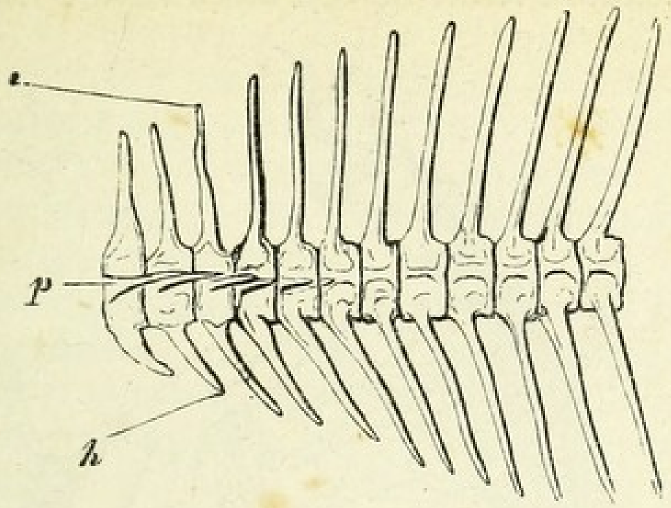

FIG. 189.—PART OF THE VERTEBRAL COLUMN OF A SOLE.

n, the summit of one of the epaxial arches; *h*, the apex of one of the hypaxial arches; *p*, one of the paraxial elements.

These elements are developed beneath the skeletal axis (the centra), and therefore in the line of tissue by which are suspended the internal plates of the primitive ventral laminæ. They have been therefore called *hypaxial*.[1]

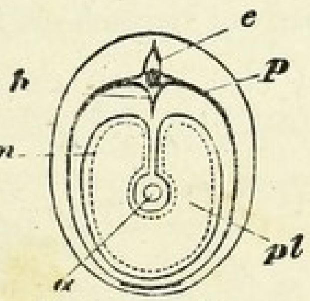

FIG. 190.—DIAGRAM OF THE FURTHER DEVELOPMENT OF THE TRUNK AS SHOWN IN A SECTION SIMILAR TO THE LAST.

a, alimentary canal supported by a mesentery[2] formed of the dorsal portion of the inner parts of the split wall of the embryonic ventral laminæ; *e*, epaxial arch; *h*, hypaxial arch descending in the median line in the root of the inner part of the split wall of the ventral laminæ; *p*, rib, bifurcating proximally and abutting ventrally against the sternum, which thus completes the paraxial arch; *m*, peritoneum, bounding on all sides *pl*, the pleuro-peritoneal space.

Hypaxial processes may also be developed beneath vertebræ to which complete paraxial arches are annexed, as *e.g.* in the thoracic region of many Birds.

11. Are there yet other elements of this hypaxial system present in man's skeleton?

[1] From ὑπό, under (the axial skeleton).

[2] For the explanation of a "mesentery" see Lesson XI.

We have seen that the branchial arches of Fishes form a series of arcs beneath the head. Moreover they grow smaller and more contracted from before backwards, *i.e.* post-axially.

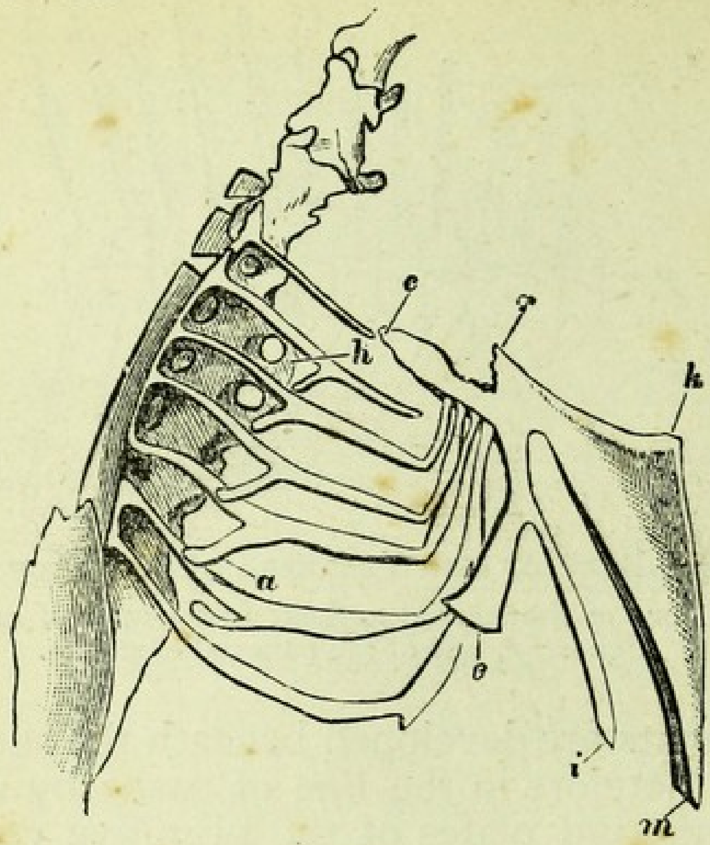

FIG. 191.—Skeleton of the Thorax of a Bird, showing the hypaxial processes, *h*, descending, which are furnished with complete paraxial arches.
(For parts of sternum see Lesson II.)

These arches are of the same essential nature as are the hyoidean arch, the mandible, the palatine arch, and the trabe-

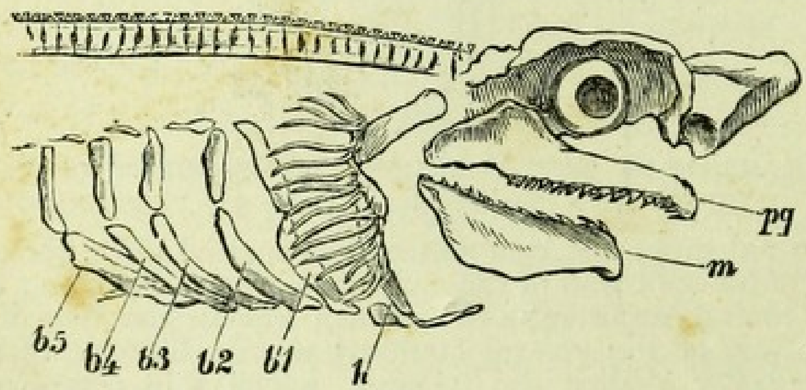

FIG. 192.—SKULL AND BRANCHIAL ARCHES OF A SHARK.
*b*1—*b*5, branchial arches ; *h*, hyoidean arch ; *m*, mandible; *pq*, palato-quadrate arch.
(*From the College of Surgeons' Museum.*)

culæ cranii, for (as we shall hereafter see) the relations of the nerves and blood-vessels which skirt them are similar.

In Fishes, the heart and great blood-vessels are outside the branchial arches, and therefore (as these vessels indicate the line of the pleuro-peritoneal division of the ventral laminæ) such arches belong to the hypaxial category of hard parts. Nevertheless, as they are placed *beneath* the anterior end of the alimentary tube, they evidently do not exactly answer to those hypaxial elements of the coccygeal vertebræ, the hypapophyses—for these, in Crocodiles and others, are placed *above* the posterior continuation of the intestinal tube. At the same time they cannot answer to ribs and sternum (*i.e.* cannot be paraxial parts), for such parts must be *outside* the line of the pleuro-peritoneal cavity.

Thus it appears that man's upper and lower jaws, and also his hyoidean apparatus, not only belong, as we have seen, to a group of skeletal parts, which become much more developed in Fishes, but that this whole group forms one special division of a skeletal category (the hypaxial), the parts of which may be termed *splanchnapophyses*.[1]

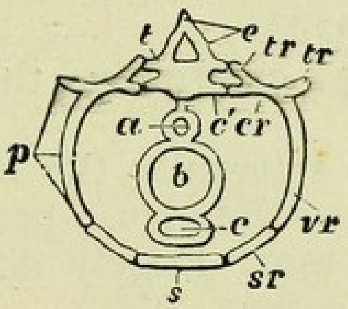

FIG. 193.—DIAGRAM OF A TRANSVERSE VERTICAL SECTION OF THE MOST DEVELOPED SKELETAL SEGMENT, ACCORDING TO THE CONCEPTION PUT FORTH IN THIS CHAPTER.

From above the centrum the epaxial parts, *e* (neural arches and neural spine), ascend. From each side of the centrum the paraxial system, *p*, proceeds outwards and downwards to coalesce with the sternum below.

t, tubercular process ; *tr*, tubercular part of the rib ; *tr'*, its continuation outwards towards the surface of the body ; *c'*, capitular process ; *cr*, capitular part of the rib ; *vr*, vertebral rib ; *sr*, sternal rib ; *s*, sternum ; *a*, part of the hypaxial system related to the great vessels (hypapophysis) ; *b*, part of the same related to the alimentary tube (splanchnapophyses) ; *c*, part related to the heart.

12. The backbone of man, then, is a partial realization of a complex axial skeleton, as thus :—

(1) A central axis, terminating anteriorly behind the pituitary fossa, and posteriorly at the end of the spine itself, segmented antero-posteriorly (*i.e.* divided into the bodies of the vertebræ), the segments having relation to the nerves coming out from the spinal marrow—*central parts.*

(2) A superior cylinder, also segmented (the neural arches), generally developing articular processes, and sometimes others besides—*epaxial parts.*

[1] From σπλάγχνα, entrails, and ἀπόφυσις, because they are related (laterally or inferiorly) to the alimentary tube.

(3) An inferior cylinder, external to the pleuro-peritoneal cavity, and segmented (ribs, &c.)--*paraxial parts*. These may be subdivided into two series :—

(*a*) Tubercular processes (*diapophyses*) and upper ribs.

(*b*) Capitular processes (*parapophyses*), lower ribs, sternal ribs, and sternum.

These two series generally, as in man, coalesce, and the component parts may have various relations of position to the body and neural arch from which they spring.

(4) An inferior cylinder, internal to the pleuro-peritoneal cavity, or directly above the origin of the internal walls of that cavity—*hypaxial parts*. These may be subdivided into three possible series, two of which are known to be actually developed as *hard* parts :—

(*a*) Parts above the alimentary cavity or its prolongation, and in relation to the great blood-vessel immediately below the central axis (*hypapophyses*).

(*b*) Parts bounding externally the alimentary canal (*splanchnapophyses*).

(*c*) Parts bounding externally the heart or great vessels, but of course internal to the pleuro-peritoneal cavity.

Hypapophyses are most largely developed in Cetaceans and Fishes, such as the Sole.

Splanchnapophyses are only formed in the region of the head and immediately behind it, and form the trabeculæ, the jaws, and the hyoidean and branchial arches.

Sometimes, as in the Lamprey, splanchnapophyses may be absent as hard parts, but in the region where they would

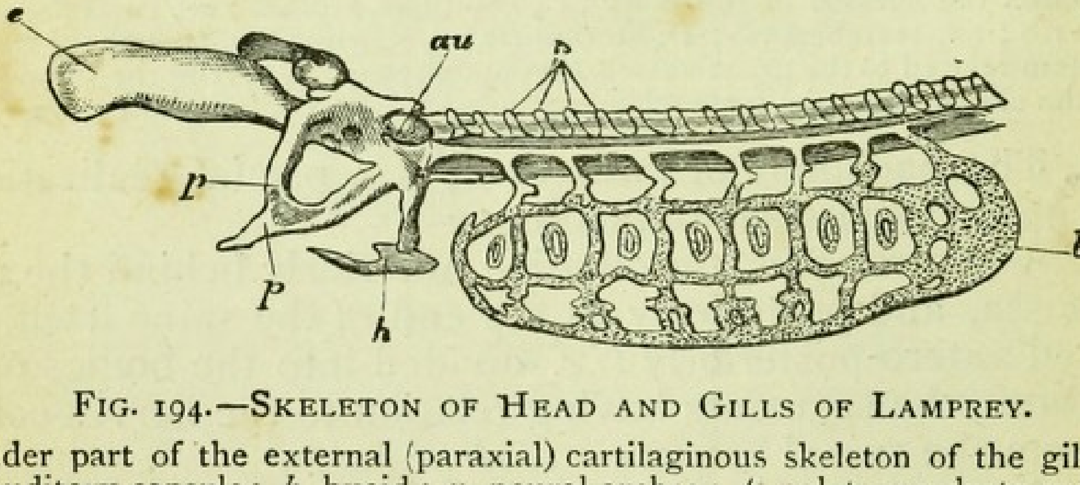

FIG. 194.—SKELETON OF HEAD AND GILLS OF LAMPREY.

b, hinder part of the external (paraxial) cartilaginous skeleton of the gills; *au*, auditory capsule; *h*, hyoid; *n*, neural arches; *p*, palato-quadrate arch.

be developed, if at all, we find a system of paraxial cartilages, bounding the gill chambers externally.[1]

[1] See Lesson XII.

Sometimes, as in the Sharks, not only are there solid splanchnapophyses, but there are at the same time external

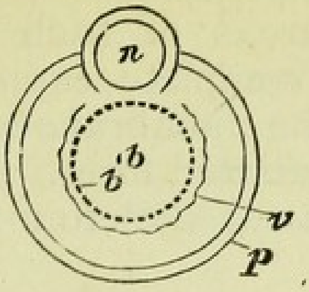

FIG. 195.—DIAGRAM OF THE CONDITION OF THE SKELETON IN THE BRANCHIAL REGION OF A LAMPREY (transverse vertical section).

n, neural canal; *b*, alimentary canal, only bounded by *b'*, which is a membranous representative of splanchnapophysial parts; *v*, the ascending vessels; *p*, the paraxial system (external cartilaginous skeleton of the gills), or branchial basket.

paraxial cartilages (like those of the Lamprey) coexisting with the splanchnapophysial hard parts of the branchial region.

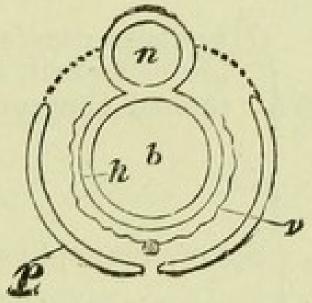

FIG. 196.—DIAGRAM OF THE CONDITION OF THE SKELETON IN THE BRANCHIAL REGION OF SOME SHARKS (transverse vertical section).

n, neural canal; *b*, alimentary canal, surrounded by solid visceral hypaxial parts (splanchnapophyses); *v*, the aortic vessels, extending up outside the branchial arches and inside the paraxial system (*p*), here represented by certain external branchial cartilages.

The general summary of the endo-skeleton here given refers, of course, to the skeleton in its most developed condition, and expresses the greatest complexities exhibited to us amongst the whole series of vertebrate animals. But, as the most perfect skeleton is at one time an embryonic structure devoid of both bone and cartilage, so in the lowest of Vertebrates the skeleton is (as we have seen) in a soft, membranous condition. In lieu of the complex differentiation of higher forms, we find in *Amphioxus* only sheets of membrane, or lamellæ, placed more or less at right angles to the very long axis of the body and proceeding outwards from the notochord to the skin.

The whole series of such membranous body-girdles may be considered as the precursor of the axial system, and the parts of such lamellæ as foreshadowing the future cartilaginous and bony complexities which come ultimately to occupy parts of the areas of such lamellæ. Such complexities are the most complete expression known to us of the axial skeleton, as the membranous lamellæ are its most imperfect and undifferentiated form.

The parts of the axial skeleton may be tabulated as follows :—

Central Bodies of vertebræ (or notochord).	Epaxial . .	Neural spines.	
		Neural arches	Prozygapophyses. Postzygapophyses. Metapophyses. Anapophyses. Hyperapophyses. Zygantrum. Zygosphene.
	Paraxial . .	Diapophyses—upper ribs.	
		Parapophyses—lower ribs and sternum.	
	Hypaxial .	Hypapophyses (either single or forked, or as detached chevron bones).	
		Splanchnapophyses . .	Trabeculæ. Mandible. Cornicula and hyoid. Cornua and hyoid. Branchial arches.
		Ventral boundary of the heart-sac, never ossified or chondrified.	

13. We may now specially consider the anterior end of the axial skeleton, reviewing the structure of man's skull in the light afforded by the study of other animals.

That division which was made at starting between the skeleton of the face and of the brain-case now appears to have been both true and significant.

All the face and both jaws are, we have seen, ossifications around the anterior splanchnapophyses, and are but of small size compared with the same parts as developed even in some members of man's own class (*e.g.* the Whale). Moreover, we have seen that such parts in him are but mere rudiments of what may be developed in other animals, as is made manifest in Fishes, with their largely developed branchial skeleton and complex suspensorial apparatus for the jaws.

14. The cranial characters presented by man may be indicated in the following generalized manner :—

The skull may be said to consist of a central axis (formed by the basi-occipital and basi-sphenoid), to which ascending and descending arches are annexed, and in which certain structures are intercalated.

We have the occipital arch, and in front of this a second arch formed by the great alæ of the sphenoid and the parietals,

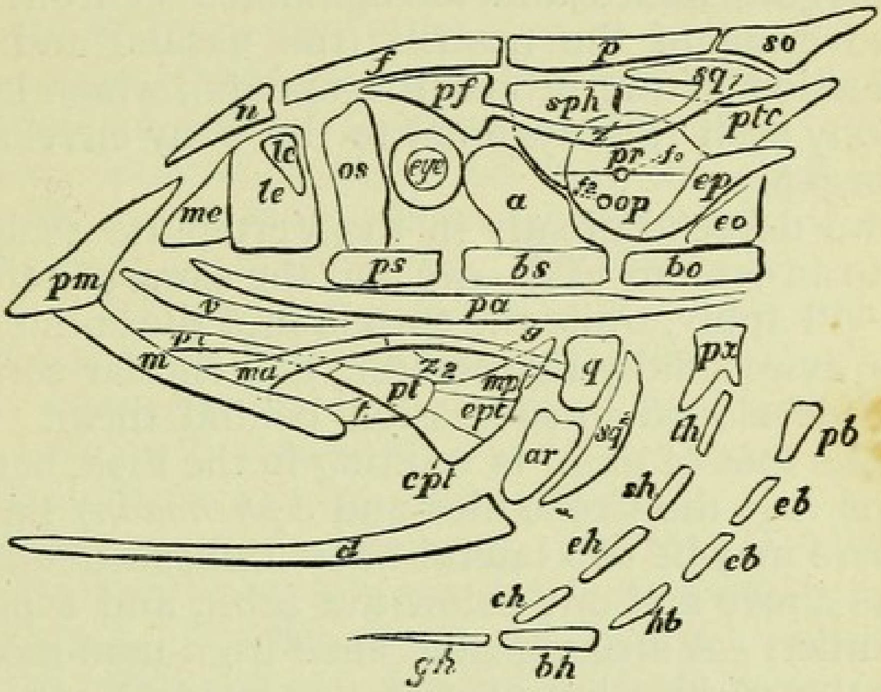

FIG. 197.—IDEAL, GENERALIZED DIAGRAM OF AN OSSEOUS SKULL.

a, ali-sphenoid ; *ar*, articulare ; *bh*, basi-hyal ; *bo*, basi-occipital ; *bs*, basi-sphenoid ; *cb*, cerato-branchial ; *ch*, cerato-hyal ; *cpt*, ecto-pterygoid ; *d*, dentary ; *eb*, epi-branchial ; *eh*, epi-hyal ; *eo*, ex-occipital ; *ep*, epiotic ; *ept*, ento-pterygoid ; *f*, frontal ; *fo*, fenestra ovalis ; f^2, fenestra rotunda ; *g*, quadrato-jugal ; *gh*, glosso-hyal ; *hb*, hypo-branchial ; *lc*, lachrymal ; *le*, lateral-ethmoid ; *m*, maxilla ; *ma*, malar ; *me*, median-ethmoid ; *mpt*, meta-pterygoid ; *n*, nasal ; *op*, opisthotic ; *os*, orbito-sphenoid ; *p*, parietal ; *pa*, para-sphenoid; *pb*, pharyngo-branchial ; *pf*, post-frontal ; *pl*, palatine ; *pm*, pre-maxilla ; *ps*, pre-sphenoid ; *pt*, pterygoid ; *ptc*, pterotic; *px*, hyo-mandibular ; *q*, quadratum ; *sh*, stylo-hyal ; *so*, supra-occipital; *sph*, sphenotic; sq^1, squamosal ; sq^2, pre-operculum ; *t*, os transversum ; *th*, tympano-hyal ; *v*, vomer ; z^1, upper zygoma ; z^2, lower zygoma.

and, again in front, a third arch formed by the orbital alæ and the frontal.

Into the median gap bounded by the arch of the frontal, the olfactory organ (the ethmoid) is, as it were, thrust.

Into the gap left on each side between the lateral occipital and the great ala of the sphenoid, the auditory organ (the temporal bone) is thrust.

Similarly, the much smaller lateral gap left between the great ala and the orbital wing of the sphenoid is related to the organ of sight, which, though not ossified in man, like the olfactory and auditory organs, is protected by bony expansions (the bony orbit) round it.

Beneath the basis cranii we have (1) the great cornua of the hyoid, which send up no connecting ligaments to it, but which through the basi-hyal are connected, by the lesser cornua, with the styloid processes. (2) In front of this hyoidean arch we have the mandibular arch, and (3), again in front of this, the arch of the upper jaw, ending posteriorly in the pterygoid bones and amalgamated in front with the osseous covering of the nostrils (the nasals) and with the outer protection of the orbits (the malars), which latter send back a bony arch (the zygoma) to the bony envelope of the auditory organ.

15. If we descend greatly in the Vertebrate scale—as, for example, to an osseous Fish—we find the same generalized description will apply, while the cornua and the cornicula of the hyoid are more solidly represented, and similar serial homologues are developed in succession behind them. A lateral zygoma (like that of man) is wanting in the Fish, but intermediate forms (*e.g.* the Crocodiles and *Sphenodon*) have shown us that there may be two lateral bony arches extending backwards, one above and one below the orbit, and separate one from the other. A striking difference from man may be presented by the ossification around the internal ear in Fishes, where, instead of being in one bony piece, hardly visible but at the base of the skull, it may be in five distinct pieces, visible at the back and the roof of the skull, and forming a very large part of its side wall. Many other differences also exist, the more important of which have been noted in Lesson III.

As has been said more in detail in that Lesson, the bones of the face, including the jaws and hyoidean and branchial arches, are all ossifications in and about the cartilaginous arcs of the several visceral arches, or splanchnapophyses.

16. Since the facial parts may be reckoned to be splanchnapophysial, and therefore, as we have seen, more or less related to the hypapophyses of the trunk (because hypaxial in their nature), it remains for us to consider what are the most general relations of the cranial (as distinguished from facial) parts of man and of other Vertebrates—to what category of spinal axial parts may they be said to appertain?

As the side walls of the cranium are developed in the laminæ dorsales, and in part invest the notochord, they must be reckoned to be essentially epaxial parts; but are they so in the sense that each of the successive cranial arches (each *cranial* segment) answers to the centrum neurapophyses and neural spine of a vertebral arch (or *spinal* segment)—*i.e.* are they modified vertebræ? To this it must be replied that in development the parts which transitorily or permanently represent in cartilage the bony brain-case of man are never serially segmented, and thus differ fundamentally from the cartilaginous predecessors of the bony vertebræ. Nevertheless, it cannot be denied that there is a singular and striking reminiscence of vertebræ in the three arches of the bony skull. Certainly, if the essence of vertebræ consists in being a series of bony rings fitted together and enclosing the nervous centres, then it must be asserted that the skull is in part composed of three bony vertebræ. Moreover the condition, before described, of *Bagrus* (Fig. 60) shows how undoubted vertebræ may become expanded, like the bony arches forming the cranial walls. In their mode of development, however, these cranial segments certainly do not agree with true vertebræ, though they have this singular secondary and induced resemblance to such skeletal parts.

It may be objected, however, that the number of the splanchnapophysial arches does not correspond with that of the cranial ones. To this it may be rejoined, either (1) that, as is very probably the case, more numerous primitive cranial segments have coalesced or ceased to be developed, though their hypaxial members still persisting, point to their former existence; or (2) that though the paraxial and hypapophysial arches correspond in number with the vertebral segments of their respective regions, yet that the splanchnapophysial arches, belonging to a category by themselves, may really answer to the existing epaxial arches, and this as follows:—

The trabeculæ to the first arch;

The palatine arch to the sphenoidal arch;

The mandible to the occipital arch;

The hyoid and cornua to the atlas;

The hyoid and cornicula to the axis; and

The succeeding splanchnapophysial arches to the several succeeding cervical vertebræ or their representatives in lower animals. On the other hand, it may be that these arches correspond with aborted vertebræ, all the centra of which are, in existing animals, represented only by the basi-occipital and basi-sphenoid.

17. We may now review man's limb-bones (or appendicular skeleton) in the most generalized way.

In the first place, it appears that the appendicular apparatus is, in the developed skeleton, no mere portion of the axial skeleton, but is (in all forms as yet known) a distinct system of parts appended to and more or less closely and variously connected with the axial system.

18. The upper limbs in man are suspended, as we have seen, from an incomplete bony girdle attached to the backbone on its dorsal aspect, by soft parts only; but on the ventral aspect abutting against the median portion of the paraxial system, *i.e.* against the sternum—doing this, nevertheless,

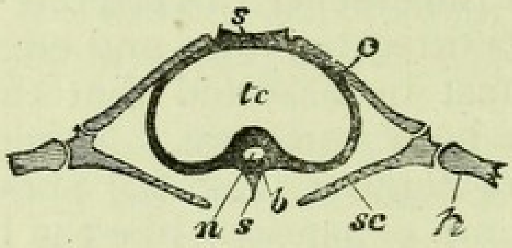

FIG. 198.—Transverse Section of the Thorax of Man, showing the relation borne by the appendicular skeleton (shoulder-girdle) to the axial skeleton: the latter is represented by the black parts of the figure.

n, neural canal; *s*, neural spine; *tc*, thoracic cavity; *s*, sternum; *c*, clavicle; *sc*, scapula (cut through); *h*, head of the humerus.

only with the clavicles. We have seen, however, that man has but an imperfect shoulder-girdle compared with what is possible, for in some animals this part joins the sternum by great coracoids, to which pre-coracoid bones are appended, as in *Echidna;* and in others, as *Raia*, it abuts against the neural axial canal, thus becoming a really complete shoulder-girdle.

The humerus we have found to be a bone constantly single in all Vertebrates above Fishes—at the least. But the relations of size of its tuberosities may be reversed, and the so-called lesser, *i.e.* the ulnar tuberosity, may be the larger one.

The elbow-joint is directed backwards; but when the rudimentary limb first appears, the arm is so placed that the joint would be directed *outwards*. Later, the elbow becomes rotated backwards.

When this rotation is effected the palm of the hand would be directed forwards (*i.e.* pre-axially), but that by the movement of pronation it becomes directed backwards (*i.e.* post-axially) or downwards—as when we rest the palm of the hand on a table.

19. In the primitive, embryonic position, the back of the humerus, the olecranon, and the back (or as it is called, from its muscular relations,[1] the *extensor* surface) of the hand are

[1] See Lesson VIII.

all directed outwards, the thumb being turned forwards (pre-axially), and the little finger of course at the opposite side of the hand. The arm being placed in this position, and a line drawn from the limb root to the tip of the middle finger, all that is in front (man being supposed to be in the horizontal attitude of a quadruped) of such a line is called *pre-axial*, all that is behind it *post-axial*, directions corresponding with those already indicated by the same term with regard to the backbone.

20. The skeleton of the fore-arm and hand is divisible into a tri- and a bi-digital series, placed side by side.

Thus there is, first, the radius ; the scaphoides and lunare ; the trapezium, the trapezoides, and the magnum ; the first, second, and third metacarpals ; and the annexed digits—forming the tri-digital series.

We have, secondly, the ulna ; the cuneiforme ; the fourth and fifth metacarpals ; and the corresponding digits—forming the bi-digital series.

Such being some of the leading points in the skeletal structure of the pectoral or thoracic limbs, what now are the resemblances to them exhibited by the pelvic limbs, and what the differences?

21. The pelvic limbs in man are suspended, as we have seen, from a complete bony girdle firmly attached to the backbone on the dorsal aspect, its two sides meeting together uninterruptedly (at the pubic symphysis) on the ventral aspect.

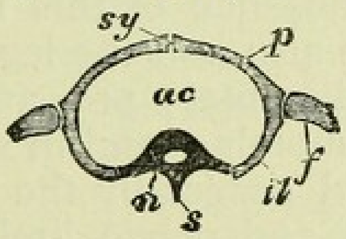

FIG. 199.—Transverse Section of the Pelvic Region of Man, showing the relation borne by the appendicular skeleton (ossa innominata) to the axial skeleton : the latter is represented by the black parts of the figure.

n, neural canal ; *s*, neural spine ; *ac*, abdominal cavity ; *p*, pubis ; *sy*, symphysis of the pubes ; *il*, ilium ; *f*, head of the femur.

Here, then, we have a great difference between the limb-girdles. This however disappears when man's pelvic girdle is compared with the pectoral girdle of the Ray (*R. clavata*), which is similar to the human pelvis in its relations to the axial system ; while in most Fishes the pelvic girdle is complete below only, but not at all above, thus resembling the pectoral girdle of man.

Instead of a union on the ventral aspect by the intervention of one bone only, as in the pectoral arch, we have the concurrence of two (the pubis and ischium), separated from each other by an interspace—the obturator foramen.

We have seen, however, that both a coracoid and a precoracoid may exist on the ventral aspect of the pectoral girdle, so that this difference also disappears on a more extended survey. Such a survey nevertheless reveals some other differences, as nothing in the pectoral girdle clearly corresponds with the marsupial bones, large ilio-pectineal processes, and os cloacæ, all of these being parts which are occasionally developed in the pelvic girdle of different animals.

The femur is constantly a single bone in all Vertebrates. In man it differs from the humerus in that the radial (or pre-axial) tuberosity is the larger of the two, while in the femur the tibial (or pre-axial) trochanter is the smaller of the two. But this difference disappears when we extend our view, as the relative size of the trochanters varies in different forms, as is the case with the tuberosities.

22. The knee-joint is directed forwards, and thus markedly differs from the elbow-joint. When, however, the rudimentary pelvic limb first appears, the leg is so placed that the knee-joint is directed *outwards*, thus agreeing with the primitive position of the thoracic limbs. Later, the knee becomes rotated forwards.

In this latter position there is no necessity for any pronation of the leg-bones to enable the sole of the foot to be applied to the ground, and the absence of this necessity constitutes a difference between the arm and the leg. We have seen, however, that a sort of rudimentary pro- and supi-nation becomes possible in some Marsupials ; and in some other animals (as the Flying Lemur, and especially the Tortoises) the position of both the pectoral and pelvic limbs is similar—through the elbow, knee, and the extensor surfaces being all directed outwards in both limbs.

In Bats the thigh is turned backwards, so that the knee bends backwards like an elbow ; and here, were it necessary to apply the sole to the ground with the digits forwards, a pronation of the leg-bones would be required.

23. The skeleton of the leg, like that of the arm, is divisible into a tri- and bi-digital series, placed side by side.

Thus there is, first, the tibia ; the astragalus and naviculare ; the three cuneiform bones ; the first, second, and third metatarsals ; and the corresponding digits—forming the tri-digital series.

We have, secondly, the fibula; the calcaneum; the cuboid; the fourth and fifth metatarsals; and the annexed digits—forming the bi-digital series.

24. In man, however, the ulna takes part in the limb joint, while the fibula does not. As we have found, however, this difference may disappear, for in some animals the fibula does articulate with the femur.

Again, in man the ulna has a large proximal process—the olecranon—while his fibula has nothing of the kind. An olecranon-like fibular structure may, however, be developed, as we have seen, in the Ornithorhynchus.

In man and in most animals there is a patella in the leg, but no analogous ossicle at the elbow-joint. Sometimes, however (as in the Wombat), there is a distinct ossicle above the olecranon on the extensor side of the elbow-joint.

25. Again, the leg in man does not articulate with the tarsus in the same manner as the arm does with the carpus—the ulna, unlike the fibula, not entering directly into such union. But the ulna may articulate with the carpus directly, even in man's own order.

The scaphoides and lunare are often together represented by a single bone which seems to answer to the astragalus, especially since the latter may be represented by two bones, as in the Salamander.

The os calcis is furnished with a great tuberosity of which there is no representative in the carpus, but then this process is not constant, as it is entirely wanting in Lizards.

The naviculare seems to have no representative in the human carpus, but even in most Apes there is an extra carpal —the os intermedium, or *centrale*.

The cuboides and unciforme of man may each be represented by two bones in other animals, so that their correspondence in unity is confirmed by a correspondence in duplicity.

The trapezium of man differs from his ento-cuneiforme in that it has a saddle-shaped surface for the pollex; but in Lemur the latter bone has a surface of that shape for the hallux.

26. The first digit is opposable in man's hand, but not in man's foot.

In *Cheiromys* and many Marsupials it is opposable in the foot, and not in the hand.

In man the digits of the hand are longer than those of the foot, but in *Macroscelides* those of the foot are the longer.

The second digit of the foot never aborts (the other digits being well developed), as we have seen to be the case with the second digit of the hand in the Potto.

Certain resemblances occur which might not be expected. Thus when, as in Birds, the distal part of the tarsus anchyloses with the metatarsus, the distal part of the carpus also anchyloses with the metacarpus, and this in spite of the greatly different use of the parts in the two limbs respectively.

But the greatest degree of resemblance between the pectoral and pelvic limbs is shown in the existing Tortoises, and in the extinct Ichthyosauria and Plesiosauria, where we find a concomitant shortening of the long limb bones, and multiplication of phalanges.

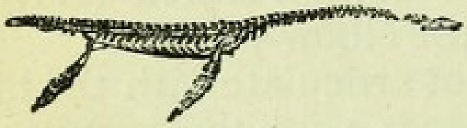

FIG. 200.—SKELETON OF PLESIOSAURUS.

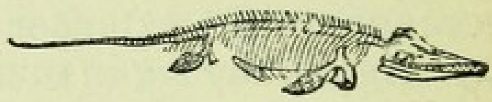

FIG. 201.—SKELETON OF ICHTHYOSAURUS.

Certain discrepancies, however, should be noted. Thus the pelvic member is never elongated or concentrated to such excess, as is the pectoral member in the Bats and the Moles. Again, we may have, as in Chameleons, three pre-axial digits opposed to two post-axial ones in the hand, and two pre-axial digits opposed to three post-axial ones in the foot.

Though in rare instances present alone, yet, when both are present, the pectoral limbs never show so persistent and considerable an inferiority of development in air-breathing animals as do the pelvic limbs in Fishes.

On the contrary, there is never a highly developed pelvic girdle without a rudiment of a pelvic limb; but we may, as we have seen in *Anguis*, have a well-developed pectoral girdle without any rudiment of a pectoral limb.

Again, we may have (as in *Lialis*) leg-bones without a foot (fig. 168), but we never meet with arm-bones without a hand.

27. It is obvious that the importance of the axial skeleton —related as it is to the brain, the spinal marrow, and the nerves which pass out from these—is far greater than that of the appendicular skeleton.

Accordingly we have found that the latter may be entirely absent (as in the Lamprey, the Ophiomorpha, and many Serpents), but that the former is constantly present in man's sub-kingdom.

The axial skeleton alone may, indeed, as in Serpents, serve the purposes of the appendicular skeleton, and become an instrument not only for climbing and swimming, but for leaping, grasping, and crushing.

We have found that both categories are always present in the two highest classes (Mammals and Birds). In the Ichthyopsida we have seen that the predominance of the axial skeleton may in some (as the Lamprey) be at its maximum, and yet that in others the appendicular one may be greatly developed while the axial one is extremely reduced (as in the Frogs).

It is the class of Birds which shows the greatest constancy in not only the existence but in the importance both of size and function of the appendicular skeleton. In them the anterior part of the axial skeleton (*i.e.* the cervical region and skull) is often modified by its great length and mobility to act as an elongated prehensile limb. This function is also performed by the posterior end of the axial skeleton in some Reptiles (*e.g.* the Chameleon), and even in some beasts, of man's own order (*e.g.* the Spider Monkeys), the tails of which (as has been before said) are so prehensile as to literally serve the purpose of a fifth hand.

LESSON VII.

THE EXTERNAL SKELETON, THE SKIN AND ITS APPENDAGES.

1. THE second category of skeletal parts remains to be considered, namely, those which together constitute the EXTERNAL SKELETON.

As has been said when the description of the skeleton was begun, fibrous tissue pervades the whole of the human frame, bounding and supporting all its organs.

With certain exceptions shortly to be noticed, it is the skin (taking this word in its wide sense) alone of all the fibrous structures which, in other animals than man, develops tissue of a dense and solid nature—horny or bony.

2. Under the head of "external skeleton," or *exo-skeleton*, will be considered the skin and its appendages, that is to say, the skin, whether external or internal, together with structures developed from or in it.

Such structures in man are the hair, nails, and teeth, but we shall find that many and diverse exo-skeletal parts may exist which have no direct counterparts in the human frame.

3. The SKIN of man invests his body pretty closely. Nevertheless the roots of the fingers and toes (especially of the three middle toes) are held together by folds of skin, and in some cases these folds extend far along, binding the digits together, and causing the person so affected to be what is called "web-fingered" or "web-toed." Such a condition is constant with regard to two of the toes in an animal so nearly resembling man in structure as the Siamang Gibbon, and is familiar to us in Ducks and Geese.

Extensions of the skin far greater than this may, however, take place. Thus, in the so-called "Flying Squirrels" the skin of the sides, between the arms and the legs, is much expanded, serving for a parachute. A skin parachute, supported by the elongated free and movable ribs before noticed, is found in the little Lizards called "Flying Dragons," and a singular fold round the neck exists in the Frilled Lizard. A pouch beneath the throat and long filamentary (merely cutaneous) processes on the back exist in some other Lizards, as in adult male Iguanas. In the Seals a fold of skin connects together the hind legs and the tail; but the maximum of skin expansion is found in Bats, as we may see in the common Bats of this country, where not only are the legs and tail bound together by a wide fold of skin, but this is continued on to and between the extraordinarily elongated fingers, to form the relatively enormous wings.

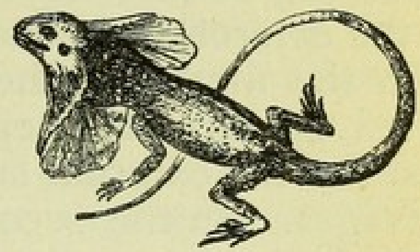

FIG. 202.—THE FRILLED LIZARD.

Folds of skin hang freely in some animals, as *e.g.* the dewlap of cattle; and peculiar folds are developed in the Rhinoceros, the thickness and denseness of the skin rendering such folds necessary to allow of free movement of the body and limbs.

The integument may be much more distensible than in man, as is the case especially in those Fishes (e.g. *Diodon*) which blow themselves out with air and then float belly upwards.

4. The skin of man, as of all other Vertebrates, consists of two LAYERS: an external layer, devoid of nerves and blood-vessels (and consequently of feeling), and a deeper layer, supplied with both, and highly sensitive. The external layer is termed the *epidermis*,[1] the deeper layer is called the *dermis*. At the lips the external layer visibly changes in texture, and inside the lips and mouth it becomes soft and moist, and is termed *mucous*[2] *membrane*. This, however, is a mere modified continuation of the external skin, and it lines the whole of the internal passages which communicate with the exterior. The superficial layer of the skin so reflected inwards is termed *epithelium*,[3] which is thus but a modified epidermis, and the common term ECTERON[4] is applied to both structures, as the name ENDERON[5] is applied to the deeper or dermal layer (*i.e.* the dermis) whereever situate.

[1] From ἐπί and δέρμα, skin.
[2] From μῦκος, μῦξα, any slimy substance.
[3] From ἐπί and θάλλω, to grow.
[4] From ἐκ, out of, and δέρος, skin.
[5] From ἐν, within, and δέρος.

The minute structure and more important characters of the dermis, epidermis, and epithelium have been described in the First and Twelfth Lessons of "Elementary Physiology."

5. As the skin (or *integument*) is thus divisible into two parts, so also the parts annexed to it are similarly divisible according as they have their place of origin in the substance of the ecteron or in that of the enderon.

In the first case they are termed ecteronic, and may be called epidermal or epithelial structures according as they arise in the external surface of the body or in the internal passages. In the second case they are called enderonic or dermal structures.

Thus our hair and nails are epidermal parts of the exoskeleton, because they are modifications of the external layer of the skin.

On the contrary, our teeth are dermal structures, because they are developed from the deeper layer or enderon.

We will consider now more carefully the skin itself before proceeding to treat of its APPENDAGES.

6. In the soft nature of his skin man agrees with the great majority of warm-blooded Vertebrates (*i.e.* of Beasts and Birds), though exceptions are to be met with even in his own class.

On the other hand, though the vast majority of cold-blooded Vertebrates (*e.g.* Reptiles and Fishes) have in one or both layers of the skin solid and dense structures, yet almost all Batrachians (Frogs, Toads, and Efts) agree with man in having an entirely soft and flexible integument.

In order to estimate the condition which man presents, it will be well to consider what the examination of other creatures shows us to be amongst the possibilities of skin-structure.

7. First with regard to the EPIDERMIS. This, as we know, is shed in man in minute fragments constantly removed by friction and ablution, and constantly replaced. Only under abnormal conditions and after certain diseases does it come away in large and continuous patches.

The case is very different in some of the lower animals. Thus the Snakes cast off the entire epidermal investment of the body—even that of the eyes—at once, and this process is repeated at intervals.

The little Efts, so common in our pools, also shed the entire epidermis at once. Separating first at the lips, the skin is pushed back over the head by the action of the fore-limbs;

the arms are then drawn out—completely inverting the ecteronic investment of each separate finger. It is then pushed back over the loins, and the legs are withdrawn, and also the feet and toes, the skin being inverted just as a glove is turned inside out. Finally the tail is pulled out, and then the whole structure being rolled up in a mass is swallowed at a gulp. It is easy, with a little patience, to shake out one of these skin-casts in water, so as to produce a complete and as it were shadowy image of the little creature that bore it.

The epidermis is never converted into bone, but is often thickened and converted into horn, an approach to which we may see in man in the labourer's hand, in the sole of the foot, and in those unwelcome deposits on the toes—corns. "Horn," indeed, is but a thickened form of the very same material as that of which the minute particles we shed from the outer surface of our skin is made, and which yield the substance "gelatine" when boiled. Certain local thickenings

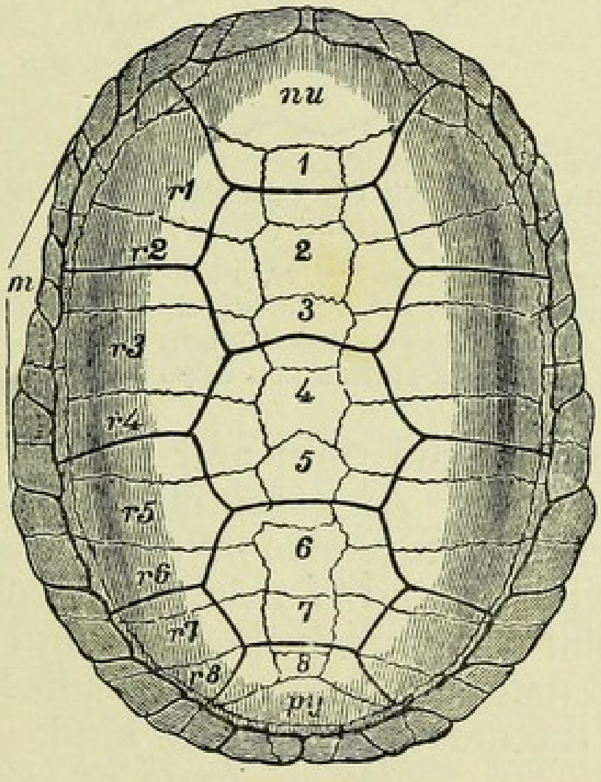

FIG. 203.—DORSAL SURFACE OF THE CARAPACE OF A FRESH-WATER TORTOISE (*Emys*).

1—8, expanded neural spines; r^1 - r^3, 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 of junction of the bony scutes.

may exist in animals, not abnormal like those above referred to in man, but constant in each species. Such thickenings are termed *callosities*, and may exist on the inner side of the legs, as in the Horse, or on the breast, as in the Camel, or be so placed as to resist the friction produced by sitting on rough branches, as in the commoner Monkeys of Africa and India.

A familiar and very valuable modification of the epidermic skeleton is known to us under the name of "tortoise-shell,"

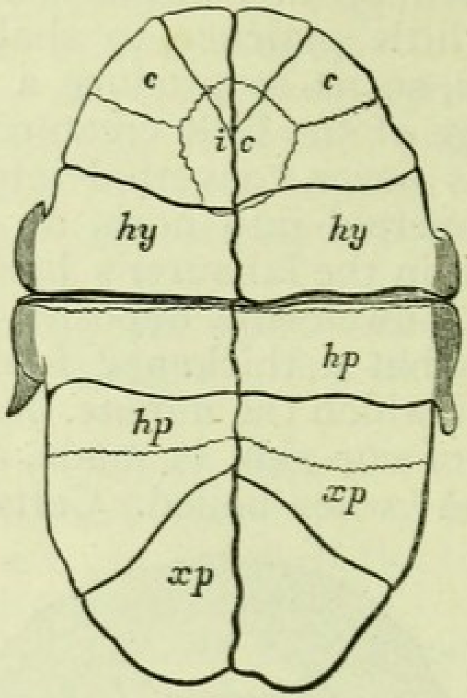

FIG. 204.—VENTRAL SURFACE OF THE PLASTRON OF A FRESH-WATER TORTOISE (*Emys*).

The bony scutes are nine in number. *ic*, inter-clavicular scute ; *c*, clavicular scute ; *hy*, hyo-sternal scute ; *hp*, hypo-sternal scute ; *xp*, xiphi-sternal scute. The horny epidermal scales are twelve in number, as indicated by the dark lines ; one such traverses each xiphi-sternal and hypo-sternal near its middle.

which coats externally the rigid and solid bony armour of a certain kind of Turtle. An essentially similar though commercially valueless structure also invests the armour of almost all kinds of Tortoises and Turtles, and consists of plates disposed in regular series upon the back and on the belly.

8. The true DERMIS often becomes ossified, constituting an exo-skeleton of the most unequivocal kind.

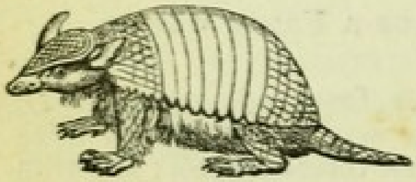

FIG. 205.—ARMADILLO.

An example of such a condition is to be found even in man's own class, Mammalia, namely, in the Armadillos. These creatures possess a very complete armour, formed of small, many-sided, bony plates (termed *scutes*), with their margins adjusted together, aggregated in masses differently in different kinds. There is generally one mass, or shield, on the head, one on the shoulders, one on the loins, with narrow bands of scutes (to facilitate motion) interposed in the mid-body region. In one form, however (*Chlamydophorus*), bony scutes are confined to the hinder region of the body, where, as has been before mentioned, they coalesce with the pelvis. In an extinct creature of the Armadillo kind (the *Glyptodon*) the armour was even more complete, as there were no moveable bands, but the body was invested, from the neck to the root of the tail, with one solid case or carapace.

In the Armadillos a horny epidermal skeleton is so adjusted to the bony case that the former is divisible into small plates or scales corresponding with the several bony scutes.

A similar co-ordinate development of epidermal scales and dermal scutes is found in some Reptiles, as in certain Lizards (*Cyclodus*), where the whole body is so doubly invested and protected, as it is also in the back of the Crocodile.

A solid investment of osseous plates may exist in Fishes, as in the bony Pike *Lepidosteus* and in *Polypterus*, but these plates will be spoken of under the head of dermal appendages, when fishes' scales are under consideration.

FIG. 206.—POLYPTERUS.

Certain Frogs (e.g. *Ephippifer* and *Ceratophrys*) develop some dorsal enderonic bony plates, which become connected with the underlying backbone, presenting an appearance which reminds us of that extraordinary development of the skeleton which we find in Tortoises.

As in the Armadillos we find bony scutes of the exoskeleton underlying horny epidermal scales, so we find beneath the tortoise-shell of Chelonians such endo-skeletal scutes together with large bony plates of the endo-skeleton; only, instead of the bony and horny structures being conformable one to the other as in the Armadillos, neither the number nor the outline of the bony plates of Chelonians corresponds with the number or outline of their superincumbent horny scales (Figs. 204 and 207).

Moreover in Chelonians, as noticed in describing the axial skeleton, the median plates of the dorsal shield (or carapace) form one with parts of the backbone, and the lateral plates form one with the subjacent ribs. Besides these dorsal plates, larger ventral scutes cover the under surface of the body, forming what is called the plastron; and in the Box-Tortoises the ends of this plastron are movable and (the head and limbs being drawn in) can be applied to the ends of the carapace, so that the whole creature becomes enclosed at will within its dense and strong exo-skeleton.

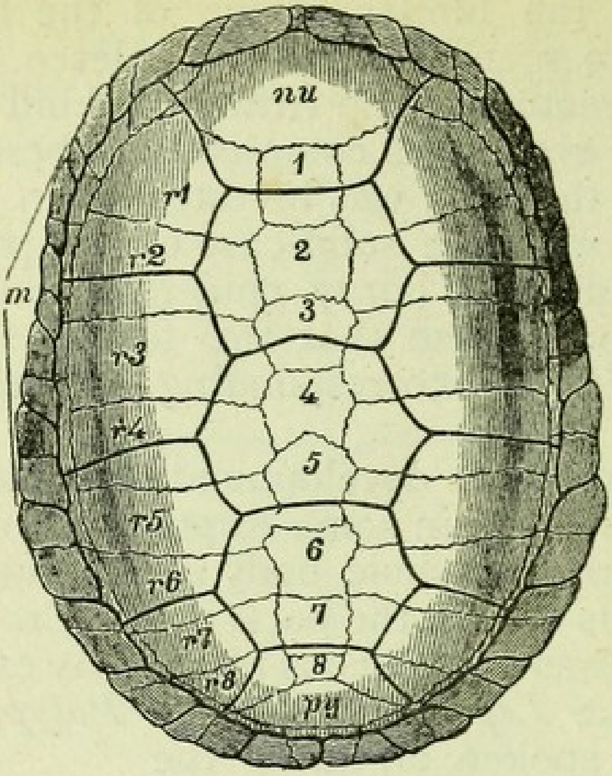

FIG. 207.—DORSAL SURFACE OF THE CARAPACE OF A FRESH-WATER TORTOISE (*Emys*).

1—8, expanded neural 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 of junction of the bony scutes.

9. In the fact that the surface of the body has a soft investment which is but very partially provided even with HAIR,

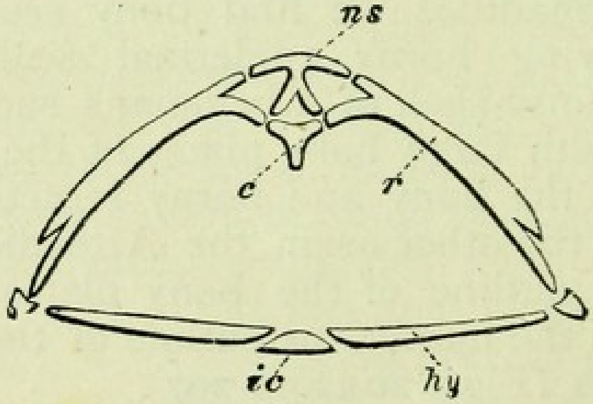

FIG 208.—DIAGRAM OF A VERTICAL SECTION OF BOTH CARAPACE AND PLASTRON OF A TORTOISE, MADE TRANSVERSELY TO THE LONG AXIS OF THE SKELETON.

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*, inter-clavicular scute ; *hy*, hyo-sternal scute.

man occupies a most exceptional position amongst Mammals. Indeed, a copious supply of hair or feathers or scales is a general characteristic of Vertebrates; and even such aquatic beasts as are destitute of hair (the Whales and Porpoises) are yet endowed with a fatty layer beneath the skin which is wanting in us. In Batrachians, however, we find a nakedness of skin greater even than in man.

In that man is provided with hairy epidermal appendages he agrees with all the members of his class except the Whales and Porpoises; but in the small amount and the distribution of the hairy investment he stands alone. In the forms nearest to him in structure, the Apes, hair is always abundant on the back, though sometimes more or less deficient on the ventral surface—the very reverse condition to that of man, in whom the back is always naked.

Long hair on the head, as also whiskers and beard, are characters variable in man and not peculiar to him, as some Apes (e.g. *Pithecia Satanas*) have a luxuriant beard.

The structure of hair, and how it is formed in a small bag (the hair sac) by the deposition of horny matter upon a little prominence (or papilla) of the dermis, which prominence rises from the bottom of the bag, have been described at length in the Twelfth Lesson of "Elementary Physiology."

The difference in structure between the hairs of the different parts of the body (as the beard, eyelashes, eyebrows, &c.) in man is but trifling. The contrast between the mane and tail of a Horse and the rest of his coat is far greater; as also between the long whiskers or feelers of many animals (as the Cat) and the rest of their fur. But the maximum of development (as it exists in man's own class) is shown in such creatures as the Hedgehog and the Porcupine, where hairs become dense and solid spines.

10. Such structures as hairs are peculiar to warm-blooded Vertebrates, but the warmest blooded class (that is, Birds) pre-

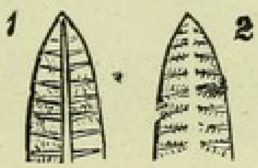

FIG. 209.—DIAGRAM OF A FEATHER PAPILLA, SEEN ON TWO OPPOSITE SIDES.
1.—Side on which is placed the deep groove in which the "shaft" is deposited and from which the secondary grooves diverge at right angles to it.
2.—The opposite side, showing the median tract where the encircling grooves vanish.

sents a peculiar kind of greatly enlarged and complex hair—called FEATHERS—found nowhere else in the animal kingdom.

A feather is formed by means of the peculiar structure of the dermal papilla which gives rise to it. That papilla (instead of being smooth, like the papilla of a hair) has on one side a deep vertical groove, broadest at the base and vanishing towards the apex of the papilla. Other less deep grooves go from each side of this vertical groove at right angles to it, and at very short distances from one another. They extend all but round the papilla, vanishing at the middle of the opposite side to that which bears the vertical groove. Grooves smaller still and much shorter are given off again at right angles to the second set of grooves, parallel therefore as far as they go to the main and vertical groove.

Now, as horny matter is deposited on the papilla, it becomes thickest where the grooves are deepest, and of course thinnest where there are no grooves at all, *i.e.* in the interspaces of the grooves. With the progress of growth, this whole horny investment splits up along these interspaces of thinnest deposit. The part which was in the main vertical groove is thickest of all, and becomes the shaft of the feather, the parts in the secondary grooves become the "barbs," and the still smaller portions at right angles to the latter the "barbules." When these last are long and hang freely, they form the sort of structure we see in an ostrich feather. Occasionally, as in the Cassowary, a feather will have two shafts; this is due to the papilla having borne a vertical groove on each side.

11. The only form of epidermal appendage, besides hair, which is found in man is the NAIL.

The structure of this organ is also explained in the Twelfth Lesson of "Elementary Physiology." It is not formed in a

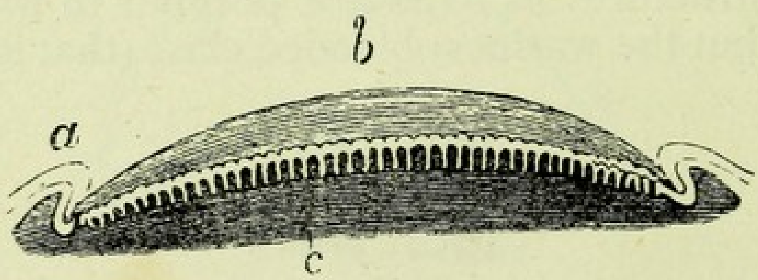

FIG. 210.—TRANSVERSE SECTION OF A NAIL.

a, small lateral folds of the integument; *b*, nail; *c*, bed of the nail, with its ridges.

bag (like a hair is), but only in a fold of skin (the root of the nail), where horny matter is deposited upon a number of minute, parallel, raised ridges of the deep layer—or dermis.

The human nails differ in shape from those of almost every other animal, in that they so little tend to surround or enclose the ends of either the fingers or toes.

The nail at its maximum of development quite surrounds and encloses the last joint of the digit which bears it, and is then called a hoof, as we may see in the Horse or Ox.

It may be produced into a sharp point, when it is called a claw, as in the familiar case of the Cat, and in Birds.

The nails may, on the other hand, be much reduced in size, and not nearly extend to the end of the digits which support them, as in the Sea Bear. They may be altogether wanting in man's own class, as in the Porpoise, or obtain a prodigious relative size, so that the body can be suspended by them, in progression, as in the Sloth. The little Bats of

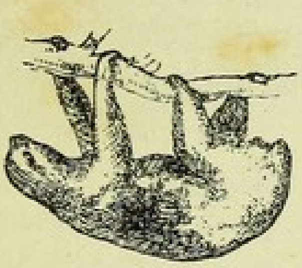

FIG. 211.—SLOTH.

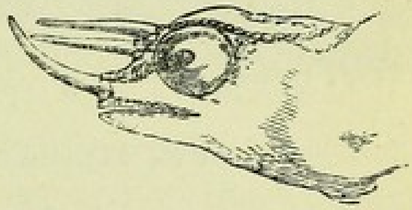

FIG. 212.—HEAD OF MALE OF OWEN'S CHAMELEON.

our own country hang, indeed, by hook-like claws when at rest; either by the claws of the toes or the two thumb-claws.

The nail of one digit may differ in form from all the others, as in that of the second toe of Lemurs and of the Hyrax.

The nail makes its appearance in its greatest simplicity in certain Toads and one of the Efts, where it is merely a slight thickening of the epidermis at the ends of the digits.

12. ECTERONIC APPENDAGES not found in man make their appearance in other animals. Thus, in the Rhinoceros we meet with a horn (or even two—one in front of the other), entirely destitute of a bony core, and growing like a great blunt nail from the dorsum of the muzzle, long dermal papillæ extending into it and answering to the dermal ridges beneath the human nail.

No less than three long horns are developed in Owen's Chameleon—one from the nose, and a symmetrical pair from the front of the head.

Other horns which do possess bony cores are developed from the head in pairs in the so-called hollow-horned Ruminants, *i.e.* the Oxen, Antelopes, Goats, and Sheep; and only in one anomalous form, the Prongbock (*Antilocapra*), are these horny structures shed at intervals; in the rest they persist throughout life. Normally there is never more than one pair amongst existing Ruminants, with the exception of *Antelope quadricornis*, which has two pairs. Such horns may be straight, or curved, or spirally twisted, but they are never branched, with the single exception of the Prong-horned Antelope.

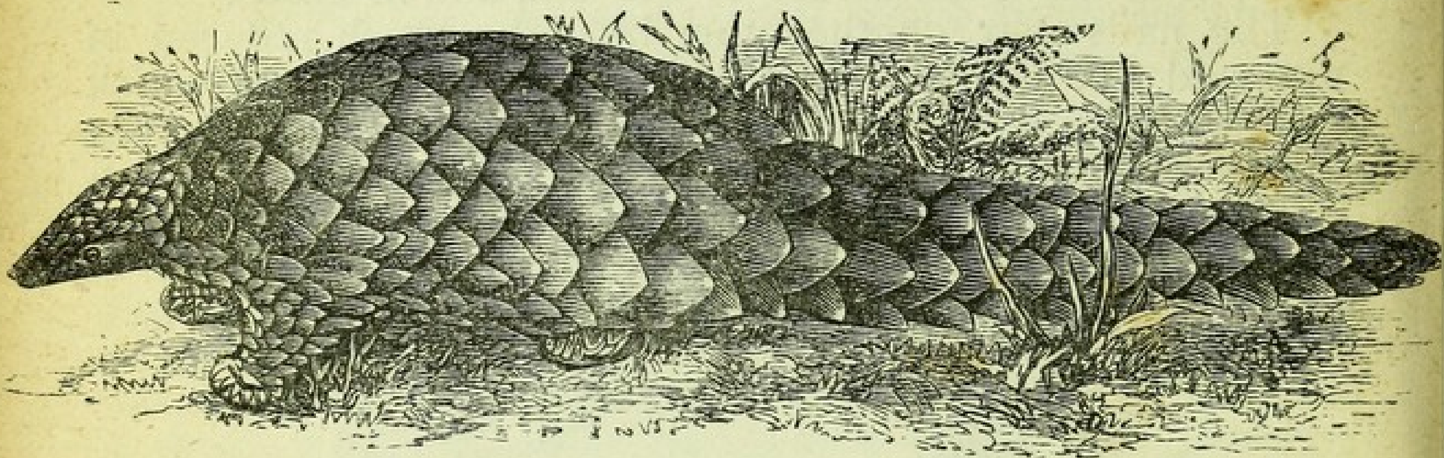

FIG. 213.—THE PANGOLIN (*Manis*).

Less familiar, but not really more remarkable, is the structure developed in the scaly Manis or Pangolin.

Here the entire body is covered and protected by strong, sharp-edged, overlapping horny plates, each of which is comparable with a nail.

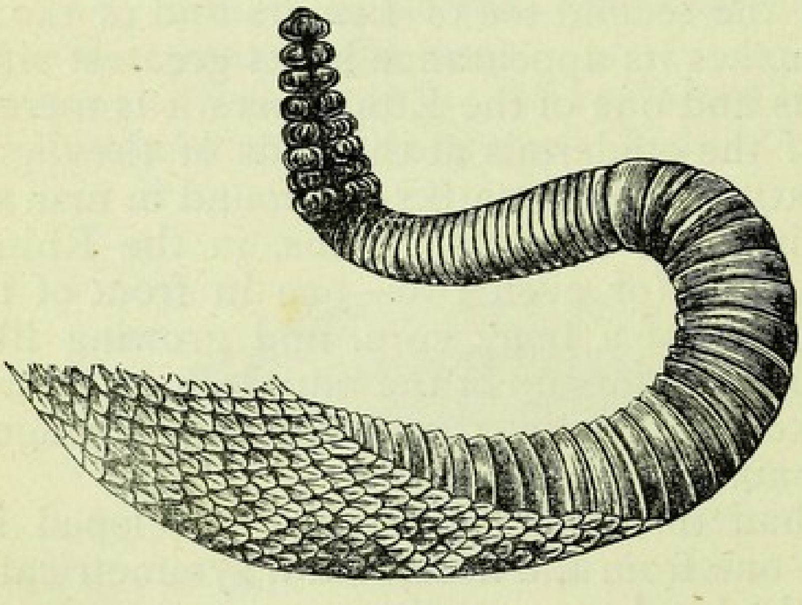

FIG. 214.—TAIL OF RATTLESNAKE.

The overlapping scales of Serpents are horny investments of processes of the dermis, but the scales of Fishes are of different nature, being formed in the dermis itself.

Curiously modified thickenings of the epidermis, which take the form of rings, may surround the ends of the tail, as in the Rattlesnake. These being loosely attached, produce a singular sound, a sort of "hissing" rattle, when the tail is vibrated by the excited animal.

Nail-like structures may also be developed from the side of the hand, as in certain Birds (e.g. *Palamedea*), and in one of the lowest members of man's own class (the Duck-billed Platypus) a hollow horny spur grows upon each ankle.

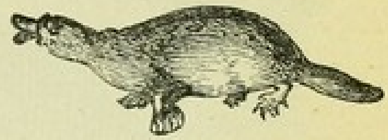

FIG. 215.—ORNITHORHYNCHUS, OR DUCK-BILLED PLATYPUS.

The epidermis of the outside of the muzzle and jaws may also be converted into horn, as in the beak of Birds and in that of the Turtle. As a remarkable exception, the same thing may take place in man's own class: this we see by the Duck-billed Platypus, which really has a horny beak very like that of a duck.

13. These being the principal modifications which investigation shows us to be possible with regard to the epidermis and its appendages, yet other peculiarities may be present in parts belonging to the other ecteronic division, the EPITHELIUM.

To begin with the mouth, its epithelial lining investing the gums becomes greatly thickened and hardened in persons who have lost their teeth, and who are so unfortunate, or so unwise, as to have failed to replace them by artificial ones.

In certain beasts, as the Cow and the Sheep, the front part of the upper jaw is always devoid of teeth, and a horny epithelial pad is formed there against which the teeth of the front of the lower jaw bite.

A much more developed structure, though essentially similar, is met with in the Dugong—a creature superficially like a Porpoise, but really very different. In this creature the front of each jaw is furnished with a dense horny plate, formed (like the horn of the Rhinoceros) of a deposit of horny matter around long processes of the deeper skin layer—the dermis. Horny substances in the place of teeth are also developed inside the mouth of the Duck-billed Platypus, and there are horny teeth in the mouth of the Lamprey.

The maximum of development of this kind of structure is, however, found in the Whalebone Whales.

The upper jaw in these creatures is furnished with very numerous horny plates (termed *baleen*), which hang down from the palate along each side of the mouth. They thus form two longitudinal series, each plate of which is placed transversely to the long axis of the body, and all are very close together. On depressing the lower lip the free outer edges of these plates come into view. Their inner edges are provided with numerous coarse, hair-like processes, consisting

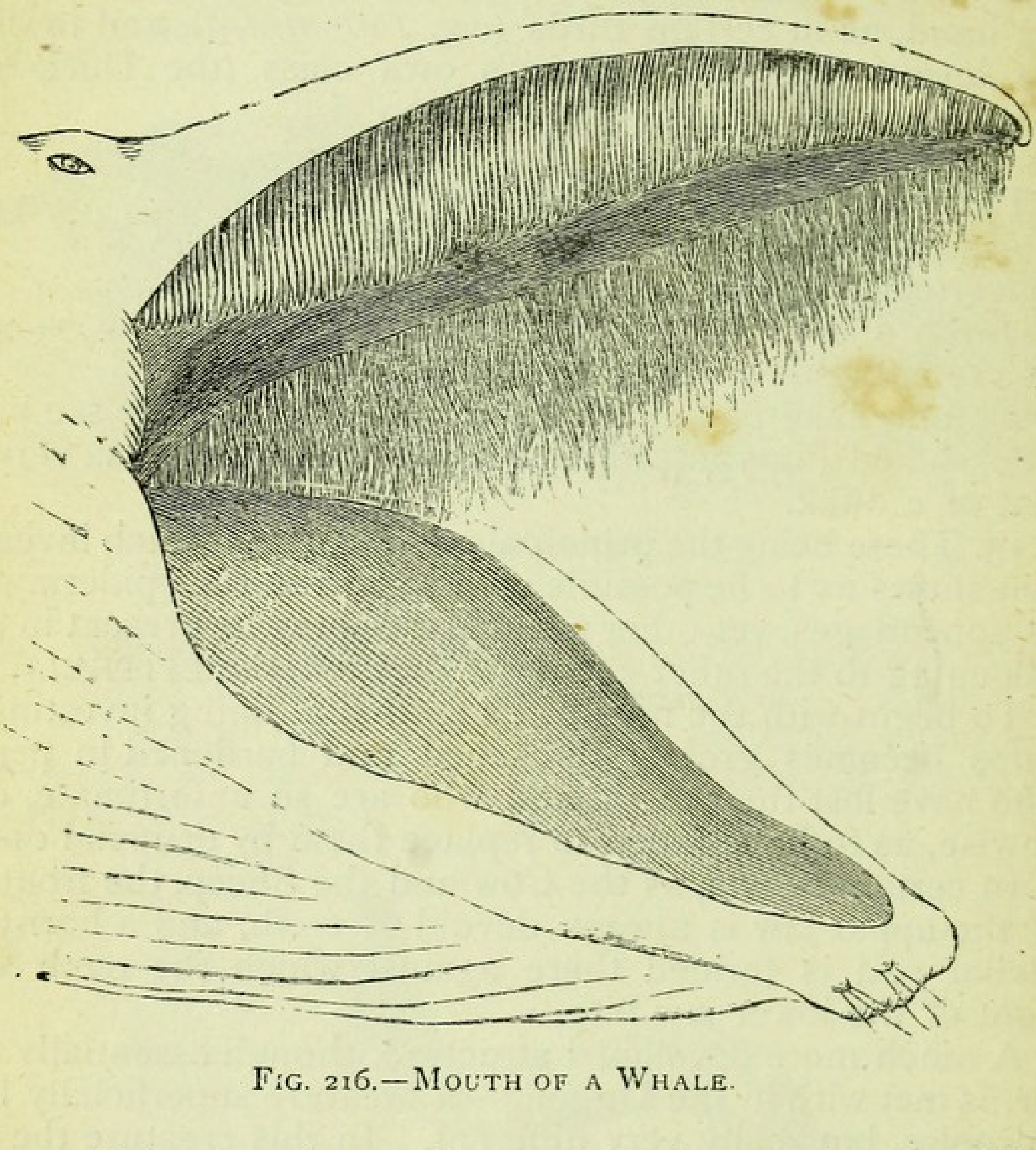

FIG. 216.—MOUTH OF A WHALE.

of some of the constituent fibres of the horny plates—which, as it were, fray out, and the mouth is thus lined, except below, with a network of countless fibres formed by the inner edges of the two series of plates. This network acts as a sort of sieve. When the whale feeds, it takes into its mouth a great gulp of water, and drives it out again through the intervals of the horny plates; the fluid thus traverses the sieve of horny fibres, which retain the minute creatures on which these marine monsters subsist.

In man a few hairs grow within the nostril. In the Rabbit hairs grow on the inside of the cheek.

The epithelial lining of the stomach may take on a dense horny structure, as in the gizzards of Birds, but this will be again noticed under the head of Alimentary Organs.

14. We come now to enderonic appendages. As has been said, that part of the dermis which underlies the epidermis is devoid of hard structures in man, who possesses them in the sub-epithelial enderon only. Such structures are the TEETH. Each tooth consists of a "crown," which is visible, and of a "fang" or "fangs," which are buried in the gum.

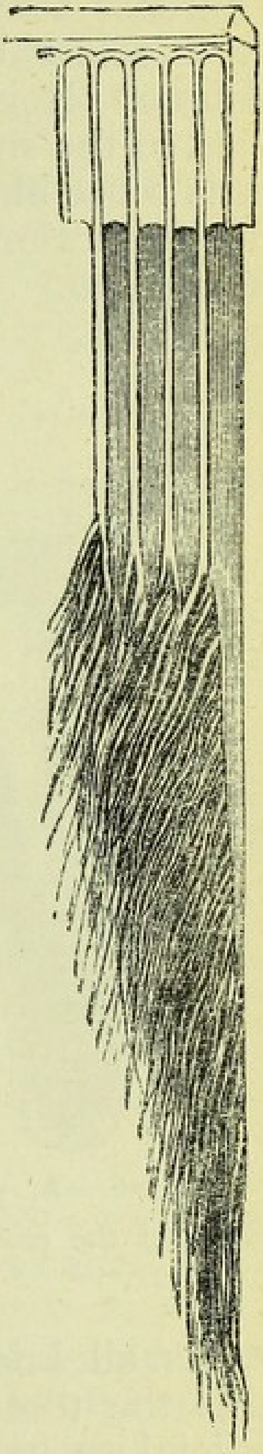

FIG 217.—FOUR PLATES OF BALEEN SEEN OBLIQUELY FROM WITHIN.

15. The mode of formation of the teeth has been described in the Twelfth Lesson of "Physiology:" how the teeth first arise as little processes (or papillæ) of the dermis, which appear at the bottom of a groove running along each side of the jaw; how the walls of the groove grow together, between and over each of the papillæ, and thus enclose the papillæ in what are called the *dental sacs.*

Each such sac is a pouch of the dermis, enclosing a "pinched off" bit of the epidermis.

The papilla, assuming the form of the future tooth, becomes hardened by a deposit within it of calcareous salts, the central part of the papilla remaining soft (as the pulp) but diminishing with the growth of the tooth, till, when the tooth is full grown, there is but a minute aperture at the bottom of each root to give entrance to very delicate vessels and nerves.

16. The STRUCTURE of each tooth, how it consists of three substances, "dentine, enamel, and cement," and the nature of each of these, have also been described in the "Elementary Physiology."

Dentine forms the bulk of the tooth ; the dense enamel coats the crown ; the cement invests the fang.

The dentine is traversed by exceedingly minute tubes which radiate into it from the pulp cavity. The enamel is the hardest structure in the human body, and almost entirely a mineral, containing but two per cent. of animal substance. It is made up of minute fibres, with their ends applied to the surface of the dentine of the tooth. The cement is more like bone ; it may take a much greater share in the formation of the tooth than is assigned to it in the teeth of man.

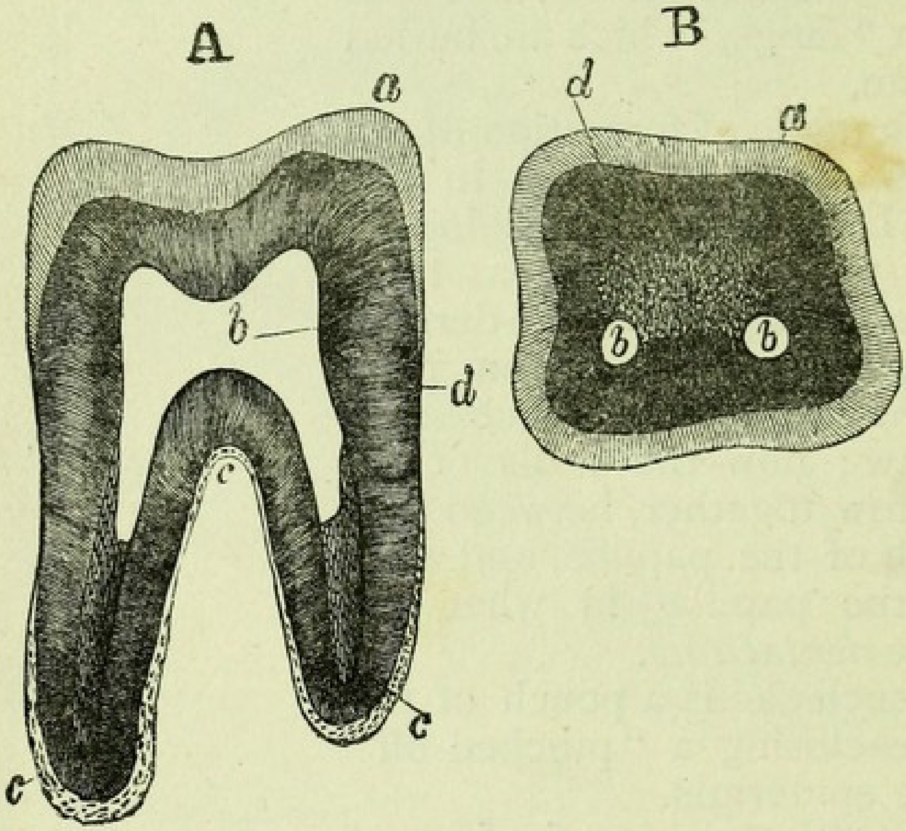

FIG. 218.—A, VERTICAL, B, HORIZONTAL SECTION OF A TOOTH.
a, enamel of the crown ; *b*, pulp cavity ; *c*, cement of the fangs ; *d*, dentine. Magnified about three diameters.

17. As all know, teeth are cut. The meaning of this is that, as the tooth develops, it rises out of its sac, the parts superficial to its apex being absorbed. As its crown rises its fang is developed.

The teeth appear successively in two sets. First the milk-teeth come into place, and afterwards the second or permanent set of teeth.

Each permanent tooth is formed in a little sac, which at first is but a prolongation of the sac of that milk-tooth which it is destined to succeed.

The development of the second tooth is accompanied by absorption of the fang of its predecessor. Replacement is not the effect of mechanical pressure, but the two actions (development and absorption) proceed harmoniously, the now fangless milk-tooth easily falling out when its successor is ready to take its place, unless through some abnormality of growth the aid of the dentist has become necessary.

Before mentioning the order of succession, the teeth themselves must be shortly described.

18. The TEETH OF MAN, when adult, should be thirty-two in number.

As the two sides of each jaw are alike, it will be sufficient to notice the eight teeth above and eight below of each side.

The fangs or roots of all teeth are firmly fitted into correspondingly shaped cavities in the bones of the jaws, which cavities are termed *alveoli*, and this mode of union of parts (like a nail driven into any substance) is termed *gomphosis*.[1]

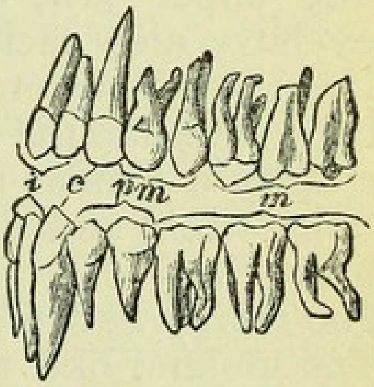

FIG. 219.—UPPER AND LOWER TEETH OF LEFT SIDE OF AN ADULT MAN.

i, incisors; *c*, canines; *pm*, premolars; *m*, molars.

The front tooth of each lateral half of the upper jaw has a chisel-shaped crown with a horizontal cutting edge. It has a single, long, tapering fang.

The second tooth is like the first, and these two, on account of their cutting shape, are called *incisors*; but we shall see that there is another reason why they belong to a special category.

The third tooth above is more pointed, more conical, and has a longer though still single fang. It is called the eye-tooth, or *canine*.

The fourth tooth above has a flatter and broader (from within outwards) crown, and bears two pointed tubercles (or cusps), one internal, the other external. Its fang is flattened and vertically grooved, showing a tendency to division, while at its end it is in general actually divided and has two apertures, one in each division.

The fifth upper tooth is like that last described, and the two, from the number of their tubercles, are called *bicuspid*, and from their more flattened crowns (better adapted for grinding) they are also called *molars*. The fifth differs from

[1] From γόμφος, a nail.

the fourth, however, in having its fang often cleft for a considerable distance from its end.

The sixth upper tooth is the largest of the whole series. It has a flattened grinding surface, with four cusps, and an oblique ridge connecting the front inner cusp with the hind outer one. The fangs are three in number, two being placed on the outer side, and one on the inner.

The seventh upper tooth is quite like the sixth.

The eighth upper (or wisdom) tooth is less large, though essentially similar. The two inner cusps of its crown are blended together, and its fangs are generally united into a single, irregular, conical mass.

The three teeth last described are all termed (for a reason which will shortly appear) *true molars.* In the lower jaw the first two teeth are similiar in shape to the first two teeth of the upper jaw, whence they are also called incisors. They have also each a single fang.

The third lower tooth is pointed and conical, and has a single root like the third tooth of the upper jaw. It therefore bears a similar name, and the *lower canine* should have its apex within and slightly in front of the crown of the upper canine.

The fourth and fifth teeth of the lower jaw are called *bicuspid* molars, like the fourth and fifth teeth of the upper one. Sometimes, however, the fourth has only a single cusp, and it is more canine-like than the one answering to it above.

The sixth and seventh teeth of the lower jaw are called *true molars.* Each bears five cusps, three on the outer side of each crown and two on the inner. The fangs are two to each, but each fang is vertically grooved.

The eighth lower tooth, or lower wisdom tooth, is also a "true molar," but differs from the two last described in having, generally, its fangs blended together, and in having its crown smaller than the others and more rounded.

The human milk-teeth are twenty in number: two incisors, one canine, and two molars, on each side of each jaw.

They resemble the permanent teeth, but the last molar, both above and below, does not resemble the fifth tooth of the permanent dentition (and which is its vertical successor), but it resembles the first true molar in each case, though it has nothing to do with the formation of this tooth, of which it is, as it were, the prototype.

The details of the succession of the teeth belong rather to

Physiology, but it should here be noted that not only do the permanent canine teeth come into place before the wisdom teeth, but also even before the second molar. Moreover, the last milk molar is shed before the epiphyses of the long bones are united to their shafts, and before the bones of the limb girdles have coalesced.

All the teeth of the permanent set are thus provided with temporary or deciduous predecessors, except the last three molars of each jaw. It is on account of this absence of vertical predecessors that the three hindmost teeth on each side of each jaw are called "true molars." In extending our view to other animals we shall see that true molars must be defined to be "teeth situated behind the hindmost tooth having a vertical predecessor."

19. The upper incisors are implanted in what we have seen to be a distinct bone (the premaxilla) from that in which the other teeth of man's upper jaw are implanted, while the canine is the foremost tooth implanted in the true maxillary bone. In surveying these parts in other animals we shall see that the DEFINITION of an upper incisor is "a tooth implanted in the premaxilla;" of an upper canine, "the foremost tooth of the maxilla, provided it be not at a considerable distance from the anterior end of that bone." The lower canine must be defined as "the tooth which bites in front of the upper canine," and the lower incisors as "teeth placed in front of or on a line with the lower canine, or, if this is absent, teeth corresponding with the upper incisors."

The bicuspid molars of man (not having always two cusps in other animals) are, in zootomy, termed *premolars*, because they are placed in front of the true molars. An extended view reveals facts which compel us to give to premolars generally the following somewhat cumbrous definition: "teeth behind the place of the canines and in front of the true molars, or, if the latter are absent, teeth behind the place of the canines and having vertical predecessors, or in front of molar teeth which have such predecessors."

20. Such being the dentition (*i.e.* tooth-furniture) of man, it may be conveniently expressed by the following SYMBOLS :—

I $\frac{2}{2}$, C $\frac{1}{1}$, P M $\frac{2}{2}$, M $\frac{3}{3}$, for the permanent dentition. I $\frac{2}{2}$ means "two incisors, above and below, on each side of the jaws;" C $\frac{1}{1}$ means similarly one canine in each case; P M $\frac{2}{2}$ means "two premolars on each side of each jaw;" and M $\frac{3}{3}$ means "three true molars, both above and below, on each side." Similarly the symbols D I $\frac{2}{2}$, D C $\frac{1}{1}$, D M $\frac{2}{2}$, for the milk dentition, refer in the same manner to the deciduous incisors, canines, and molars respectively.

It need hardly be added that each tooth attains its full development within a limited time, after which it grows no more, and (with very rare exceptions) no third development ever replaces the fall of a tooth of the permanent dentition.

An acquaintance with human structure only, would give the student very little idea of the possibilities of development in the matter of "teeth."

As to SITUATION, implantation, number, form, and use, and also as to succession and structure, the greatest diversities are to be found.

21. Man agrees with the whole of his class in that he is only furnished with teeth upon the margins of the jaws. Some members of his class, however, are as completely toothless as are Birds—*e.g.* the Echidna, Pangolins, and Ant-eaters.

FIG. 220.—ANT-EATER.

In Reptiles we first become acquainted with the fact that true teeth may be developed not only from the margins of the jaws, but also from the palate, as we find to be the case in the Iguana and in Serpents, some of the teeth of which latter, as will shortly be explained, present very remarkable peculiarities. When we descend to the Batrachians we sometimes find teeth in two series not only in the upper jaw, but also two series in the lower (as in *Proteus* and *Meno-*

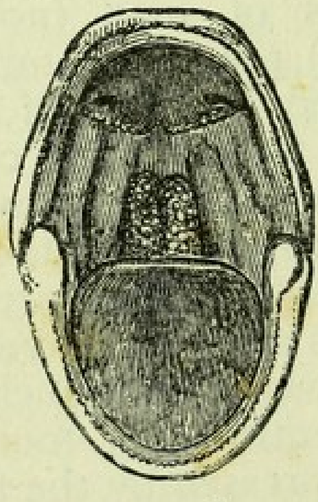

FIG. 221.—OPEN MOUTH OF THE AMERICAN EFT PLETHODON,

Showing the numerous para-sphenoidal teeth at the extreme back of the roof of the mouth, together with a row of palatine teeth placed behind each posterior nasal opening in the anterior part of the palate.

branchus), and even (as in *Plethodon*) teeth upon the under surface of the back part of the skull.

Fishes teach us that teeth may be developed in yet other situations, for in some of those animals (*e.g.* the Salmon and *Odontoglossum*), there are teeth upon the tongue; and in most Fishes teeth are developed at the extreme back of the mouth, on the bones of those arches (*branchial* arches) which represent permanently what have been spoken of in the First Lesson as the transitory posterior visceral arches of the early stages of human development. The branchial arches of Fishes which support the gills, and are placed on each side beneath the back of the head, sometimes (as in the Perch), develop tooth-like bodies on their inner surfaces, and the hinder of these lateral arches terminate (Fig. 114) in bones called pharyngeal,[1] which most frequently support teeth (sometimes of very complex structure, as in *Scarus*), termed from their situation pharyngeal teeth. Moreover, the exactly reverse conditions to those which obtain in man may be met with, as in the Carp and Tench, where the

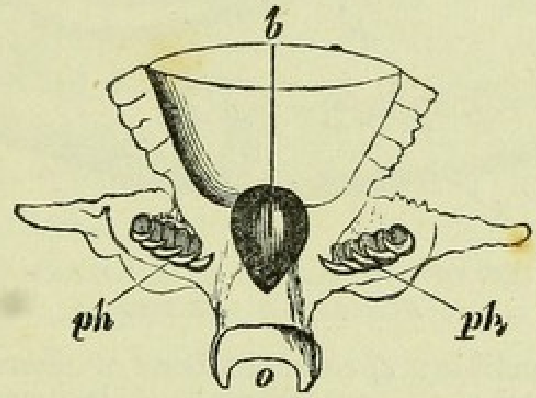

FIG. 222.—PHARYNX OF A TENCH OPENED FROM BELOW, AND THE TWO ROWS OF PHARYNGEAL TEETH DIVARICATED. (*After Owen.*)

b, basi-occipital tooth; *ph*, pharyngeal teeth; *o*, œsophagus.

margins of the jaws are as free from teeth as is man's throat, while the *posterior* aperture of the mouth is bounded by teeth, partly pharyngeal, and in part attached to a prolongation downwards of the hindmost bone of the base of the skull!

We shall see that tooth-like tissue may be developed in still more anomalous situations, but as some of the structures referred to cannot be called teeth, and others can only doubtfully be so called, notice of them may be postponed.

22. As to IMPLANTATION, the changes which take place in

[1] From being placed in the "pharynx." For this see Lesson XI.

the process of development of human teeth are interestingly illustrated by permanent conditions in other animals.

Thus we may have, as in Sharks, an open groove along each jaw, in which groove dermal papillæ appear and undergo calcification directly without their becoming enclosed in sacs at all.

We may have, as in the Pike, an enclosure of each papilla in a sac, but no development of bone round it, the teeth being attached to the jaw by ligament.

We may have teeth which become anchylosed to the summit of the jaw, there being no bony wall (or alveolus) developed on either the inner or the outer side of the teeth, as in certain Lizards (e.g. *Psammosaurus*), termed Acrodont.[1]

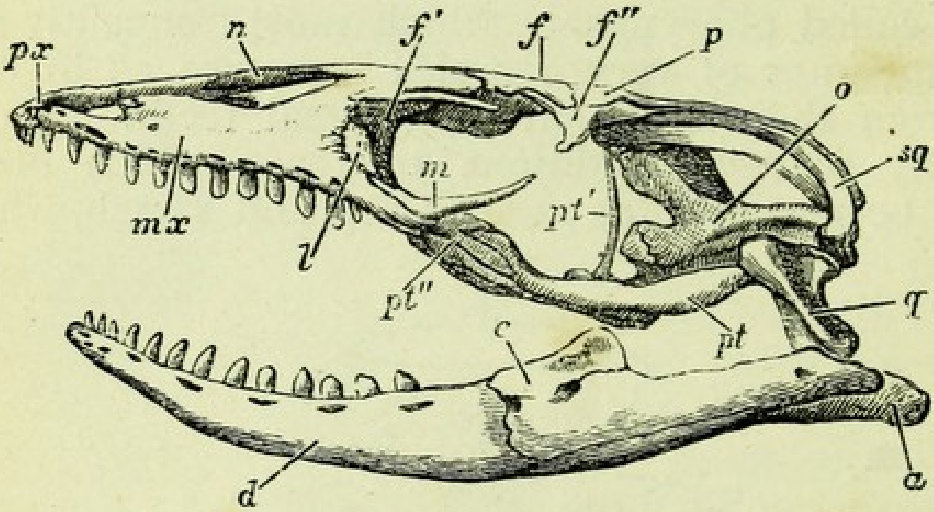

FIG. 223.—SIDE VIEW OF THE SKULL OF A LIZARD (*Varanus*), WITH ACRODONT TEETH.

a, articular bone of mandible; *c*, coronoid bone of mandible; *d*, dentary; *f*, frontal; *f'*, pre-frontal; *f''*, post-frontal; *l*, lachrymal; *m*, malar; *mx*, maxilla; *n*, nasal, *o*, pro-otic; *p*, parietal; *pt*, pterygoid; *pt'*, columella, or dismemberment of pterygoid; *pt''*, os transversum; *px*, pre-maxilla; *q*, quadrate bone; *sq*, squamosal.

We may find a development of a bony alveolar plate on one side (the outer), to which the teeth may become attached by actual bony growth (anchylosis), as in the Iguanian Lizards. Such a form of attachment is termed *pleurodont*.[2] We may find two alveolar plates of bone, but no transverse bony partitions, as in *Ichthyosaurus*.

We may find both alveolar plates together with transverse partitions forming distinct alveoli, which nevertheless are incompletely divided one from another at the hinder part of the mouth, as in many of the Dolphin tribe; and finally, we

[1] From ἄκρος, sharp, and ὀδοῦς, a tooth,
[2] From πλευρόν, a side, and ὀδοῦς.

may meet with alveoli thoroughly complete, like those of man, as in most members of his class.

These complete alveoli, however, may be in some respects different from those of man. They are so where teeth grow

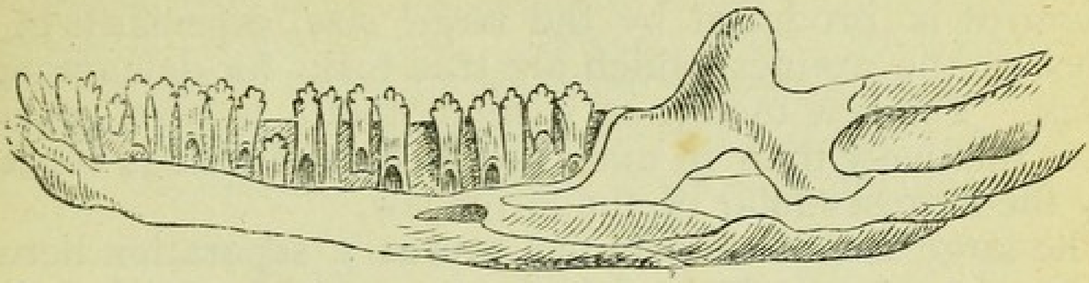

FIG. 224.—INNER SIDE OF LOWER JAW OF PLEURODONT LIZARD, showing the teeth attached to the inner surface of its side.

from permanent pulps throughout the whole of life—like the tusks of the Elephant and the teeth of many other beasts (*e.g.* the cutting teeth of the Squirrel). In such cases, of course, the deeper part of the alveolus is quite wide instead of being attenuated as in us.

23. The NUMBER of teeth in man is interesting as being not very far from that which is typical of the great bulk of the class to which he belongs. It is identical with that existing in the whole of the Apes which inhabit the old world, and those of the new world only differ from him by the presence of one more pre-molar or by the absence of a molar on each side of each jaw.

In man's own class the number of teeth developed may be very great, as in the Dolphins, where the greatest number is reached in *Pontoporia*, namely 220.

The large Armadillo (*Priodon*) may have as many as ninety. They may be reduced to two, as in the Narwhal.

If we pass out of man's class we may find teeth many or few, as in Reptiles ; but amongst Fishes we meet with every extreme, from a single pointed tooth on the roof of the mouth, as in *Myxine*, or two above and two below (flat and crushing), as in *Ceratodus*, up to such a multitude that to count them would be a task both useless and difficult, as in *Muræna*, the Pike, or *Osteoglossum*.

24. The FORMS presented by the teeth of man agree more or less closely with what we find in many members of his class, but have no relation, or only the most general and distant one, to the teeth of cold-blooded Vertebrates.

Although the shape of the teeth is nearly the same in all men, nevertheless the wisdom teeth of those races which are reputed lowest are larger and more equal to the teeth next in front of them than is the case with Europeans.

When we descend to the creatures nearest to man in bodily structure (the Apes of the old world), though we find the number of teeth identical with that in him, yet a striking difference is produced by the large size, especially in the males, of the canines, which are true tusks for defence or for attack. The last molar, or wisdom tooth, is also generally larger relatively than in man, and in some forms is considerably the largest molar of the lower jaw.

The large size of the canines causes a separation between the lower canine and the first lower pre-molar, and between the upper canine and the outer incisor, in order to provide space for their apices to pass. These interspaces are each called a *diastema*,[1] and are wanting in man, where the teeth are all normally close and contiguous. This contiguity and absence of any diastema is a character which man shares only with the little Lemur *Tarsius*, and with a certain extinct hoofed quadruped, the *Anoplotherium*.

Most Mammals have teeth of definite kinds—incisors, canines, or molars. This is not the case, however, with all, as, for example, the Dolphins have teeth which are all nearly alike.

Below the class of Mammals, only rarely in certain Lizards (*e.g.* the Agamas) do teeth simulate canines with small teeth between them in the front of the mouth simulating incisors.

25. The INCISORS of man are closely resembled by those of the Apes, but in some Apes of the new world (*Pithecia*) the lower incisors, instead of being nearly vertical, are long, slender, approximated together, and inclined strongly forwards

FIG. 225—GRINDING SURFACE OF THE TEETH OF THE RIGHT HALF OF THE LOWER JAW OF THE LEMUROID *Microcebus*, showing the close apposition of the canine to the two elongated incisors, which are almost horizontal in position.

as well as upwards—a condition still more decided in the Lemuroids. The most singular form of the Lemuroid group (the Aye-aye—*Cheiromys*) has but two incisors above and two below. These, however, are very large, and grow from permanent pulps during the whole of life, from deep

[1] From διάστημα, to separate.

roots just like those of the Squirrel or Rat. Such teeth, specially adapted for gnawing, as we so often know to our cost as regards the Rat, are denser on the front surface than elsewhere, so that the action of gnawing, as it wears away more quickly the softer part behind, keeps a constantly sharp chisel-shaped edge in front. Animals which have teeth thus formed are apt to suffer fatally from the loss of one, as, there being then nothing to wear away its natural opponent of the opposite jaw, the latter continues to grow and complete that

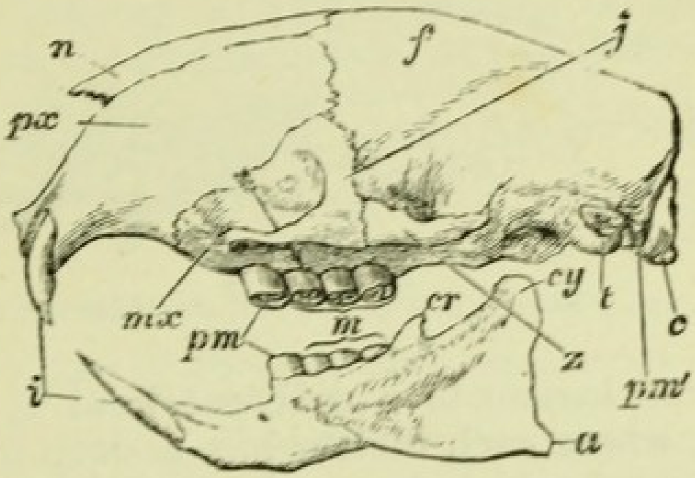

FIG. 226.—SIDE VIEW OF THE SKULL OF A PORCUPINE (*Hystrix cristata*). (TYPICAL RODENT DENTITION.)

a, angle of mandible; *c*, occipital condyle; *cr*, coronoid process of mandible; *cy*, condyle of mandible; *f*, frontal; *i*, incisor teeth; *j*, ascending branch of maxilla enclosing the enormous infra-orbital foramen, the course of the masseter muscle through which is indicated by an arrow; *m*, molar teeth; *mx*, maxilla; *n*, nasal; *pm*, premolar teeth; *pm*, paramastoid process; *px*, premaxilla; *t*, tympanic bone; *z*, zygomatic arch—the part formed by the malar.

circle of which its axis (from root to apex) describes a segment. Rabbits and Hares are not unfrequently found dead from such accidental deformity.

A pair of strong but pointed upper incisors are found in

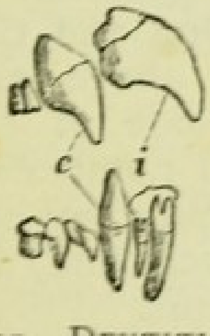

FIG. 227.—DENTITION OF DESMODUS.
i, incisors; *c*, canines.

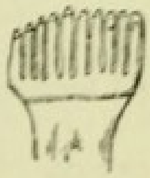

FIG. 228.—A LOWER INCISOR OF GALEOPITHECUS, showing its comb-like form.

the blood-sucking Bat *Desmodus*, and to these pointed incisors notched incisors are opposed below. In another Bat such notches are more marked, but these attain their maximum of development in the lower jaw of the Flying Lemur (*Galeopithecus*), where each incisor has the appearance of a comb, being notched by parallel notches down to the very base of the crown. (Fig. 228).

Rarely, as in certain Insectivorous Beasts (e.g. *Hemicentetes*), the upper incisor may bear more than one cusp.

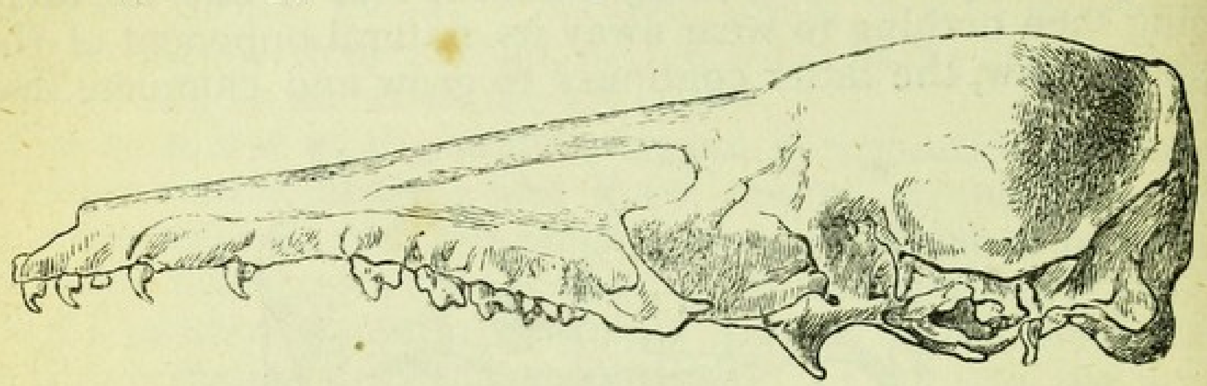

FIG. 229.—SIDE VIEW OF SKULL OF HEMICENTETES.

An excavated incisor of a different kind is familiar to us in the Horse, where each incisor has a deep median depression, the "mark," which has a form such as would be produced by the sudden inflection of the surface of the tooth so as to form a deep pit. This "mark" continues to be visible till the tooth has worn down by use beyond the point to which the inflection extends. The dark colour of the "mark" is due merely to the accumulation of fragments of food and foreign bodies within the pit.

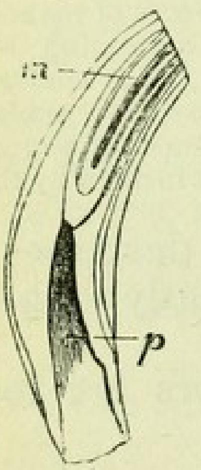

FIG. 230.—VERTICAL SECTION OF A HORSE'S INCISOR, showing the depth of the vertical fold forming the "mark" *m*.

p, the pulp cavity.

(*After Rousseau.*)

When the canine teeth are large the incisors are generally small, as we see in the Dog and Cat, where there are three above and three below on each side of each jaw. This is the typical number of Mammalian incisors, but they may be as many as $\frac{5}{4}$ on each side, as in the American Opossums.

Incisors may, on the contrary, be altogether wanting though other teeth are present, as in the Armadillos, except one kind. They may be quite wanting in the upper jaw but present in the lower, even in man's own order, e.g. *Lepilemur*.

The same is the case in some Mammals of other orders, as in the Ox, Deer, and Sheep; as also in the extinct Elephant-like creature *Dinotherium*, which had only two incisors, but these extended downwards from the front end of the lower jaw.

Incisors may be present in the form of enormous tusks in the upper jaw but wanting altogether in the lower, as in the Elephant. They may similarly be present in the upper jaw only, but exhibit a flat grinding surface flush with the gum, as in the Walrus.

The upper incisors may be separated by an interval from their fellows of the opposite side, as in *Loris*.

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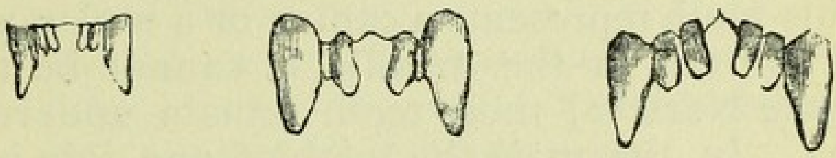

FIG. 231.—FRONT VIEW OF UPPER INCISORS AND CANINES OF THREE GENERA OF SLOW LEMURS (natural size).

1, *Loris*; 2, *Nycticebus*; 3, *Perodicticus*.

The front lower incisor may be enormous, and represent, by its notched outline, several incisors fused into one. Moreover with age the teeth may become anchylosed to the jaw.

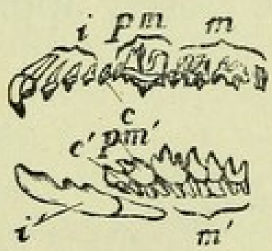

FIG. 232.—DENTITION OF SHREW-MOUSE (*Sorex*).

i upper incisors; *i'*, notched lower incisor; *c*, upper canine; *c'*, lower canine; *pm*, upper pre-molars; *pm'*, lower pre-molar; *m*, upper molars; m', lower molars.

These peculiarities are exhibited by the Shrew-Mice, which, as before remarked, are not "mice" at all, but closely allied to the Mole and Hedgehog.

Generally having but a single fang, whether with or without a permanent pulp, an incisor tooth may yet have a double fang, as is the case in the Flying Lemur and in *Petrodromus*.

26. The CANINE TEETH of man, as their name implies, find in the Dog (and other flesh-eating beasts) an enlarged representative, as also in the Apes. Such tusks, however, are far

exceeded by what we find in certain of the Hog tribe, *e.g.* in the Babyrussa (*Porcus*), where the upper canines first mount vertically and then curve over backwards and downwards, whence its native name, which signifies Deer-Hog.

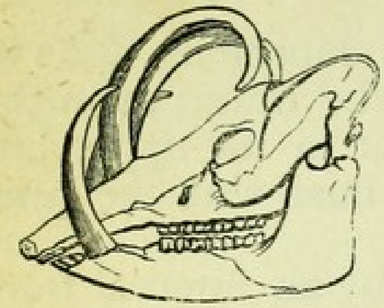

FIG. 233.—SKULL AND TUSKS OF THE BABYRUSSA (*Porcus*).

Undoubted canines attain their maximum in the upper jaw of the Walrus, which develops a pair of enormous descending tusks growing from permanent pulps, and which are said to aid the animal in its locomotion amongst the ice.

The longest tooth developed in the whole animal kingdom is the tusk of the Narwhal. It may be doubted, indeed, whether this tooth represents a canine or a molar, yet, as it is embedded entirely in the maxilla, it cannot be an incisor. In the female Narwhal these teeth remain undeveloped and in the bone. In the male the tooth of one side is generally developed, but sometimes both are so. The pulp cavity extends nearly the whole extent of the enormous tooth, which is said to attain a length of ten feet. Though straight, its surface has a spirally-twisted appearance, and formerly was sometimes exhibited as the horn of the Unicorn.

Upper canines may be present though upper incisors are wanting, as in the case of the Musk Deer and Muntjac.

Lower canines may be closely approximated to and shaped

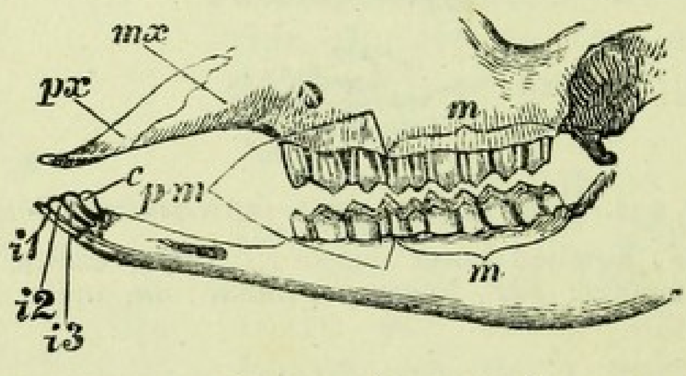

FIG. 234.—DENTITION OF A SHEEP. (TYPICAL RUMINANT DENTITION.)

mx, maxilla; *px*, pre-maxilla, which is edentulous, there being no upper incisors; i^1, i^2, i^3, three lower incisors of left side; *c*, lower canine; *pm*, premolars; *m*, molars.

like the incisors adjacent to and between them, as in the Lemurs and in the Ox and Sheep tribes.

Lower canines may be altogether wanting, though both incisors and molars are present in each jaw, as is the case in all Rodents, *i.e.* in all Rats, Squirrels, Hares, Marmots, and Porcupines.

Canines may grow from a root essentially similar to that of man's canine, or from a double fang, as in *Galeopithecus* and the Mole. On the other hand, as has been said, they may grow from permanent pulps.

Very rarely, *e.g.* in the Tanrec (*Centetes*), the points of the lower canines are received into corresponding pits on the under surface of the upper jaw.

27. The MOLAR TEETH of man present a medium character when compared with those of the other members of his class. Often we find molar teeth relatively larger, broader, more complex, and more suited for grinding hard or tough vegetable substances than in him.

We see, on the contrary, that they may often become relatively smaller, narrower, and more trenchant, so as to serve better for cutting and dividing flesh.

The maximum both of size and complexity is attained by the grinders of the Asiatic Elephant, where the worn surface presents a great number of narrow transverse ridges, the nature of which will be explained under the head of Structure.

The greatest simplicity of form is seen in the Walrus, where each molar is perfectly simple and flat; and in the blood-sucking Bat *Desmodus*, where each molar forms a single wedge-shaped blade.

The total number of molars reaches its maximum in the existing creation in the little Marsupial *Myrmecobius*, where they are thirty-four ($\frac{8}{9}$) in number. The smallest number is met with in the Australian Rat *Hydromys*, where we find $\frac{2}{2}$.

28. The distinction between pre-molars and true molars which exists in man, exists also in the great majority of animals belonging to his class.

The number of PRE-MOLARS is often more numerous than in him, there being three even in the American Apes, and four in the Dog.

In form the pre-molars are generally, as in man, smaller and less complex than are the true molars; but in some beasts, as for example in the Horse, there is no difference in this respect.

The first pre-molars soon present a striking difference from those of man. Thus, even in the old-world Apes, the upper one has its external cusp more prolonged, and the lower one has its front edge elongated and blade-like. These teeth may assume the shape of canines, as in *Hemicentetes* and in the Camel.

29. The TRUE MOLARS are very rarely more numerous than in man, who has the typical number of the great (Monodelphous) division of his class. In the Marsupials (Didelphous Mammals), however, there are typically four above and four below.

They may (even where pre-molars are present) be quite wanting in the upper jaw, while there is but one on each side (and that very small) of the lower jaw, as in the Cats.

30. The form of the human true molars, both above and below, will readily serve to explain the more general modifications present in man's class.

The peculiar form of the upper molar—namely, four cusps, one at each angle, with the before described oblique con-

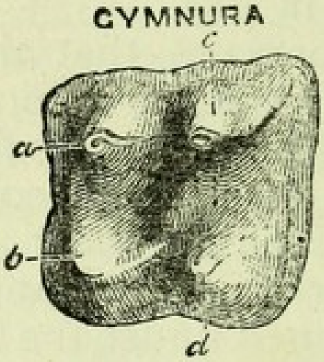

FIG. 235.—GRINDING SURFACE OF A LEFT UPPER MOLAR.
a, antero-external cusp; *b*, antero-internal cusp; *c*, postero-external cusp; *d*, postero-internal cusp.
The oblique ridge is seen passing from the postero-external cusp to the antero-internal one.

necting ridge—reappears not only in some of the Apes, but in other beasts, as *e.g.* in the Hedgehog and its ally, *Gymnura.*

A "band" of dental substance (termed the *cingulum*) may surround the tooth, and even in man's own order (Primates)

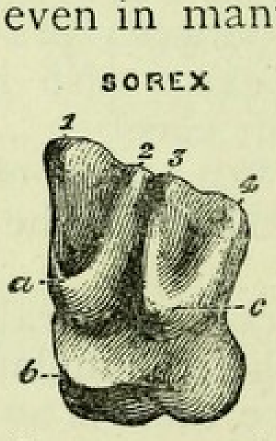

FIG. 236.—GRINDING SURFACE OF A LEFT UPPER MOLAR.
a and *b*, anterior cusps; *c*, postero-external cusp; 1, 2, 3, and 4, the four accessory cusps of the external cingulum.

may develop small accessory cusps which project downwards external to the two outer of the four principal cusps.

By further development the external cusps of the band may equal in vertical extent the four normal cusps, as in the Shrew-mice (*Sorex*).

A prominence may also be developed from the internal part of the band. When this, together with all the other prominences, is sharp-pointed (as in the Flying Lemur and the Mole *Urotrichus*), it produces a maximum of complexity of this special kind.

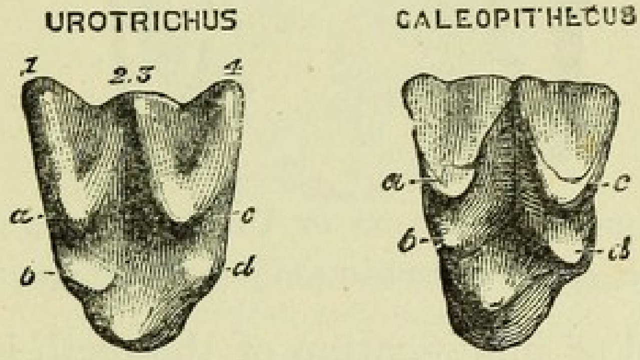

FIG. 237.—GRINDING SURFACES OF UPPER MOLARS OF LEFT SIDE.
a, *b*, *c*, and *d*, principal cusps; 1, 2, 3, and 4, accessory cusps of external cingulum.
The prominence of the internal cingulum appears below and between *b* and *d*.

Ridges may be developed to connect the two external normal cusps with the adjacent cusps of the band, thus forming two triangular prisms placed side by side, and each with a flat side turned outwards and an angle inwards; while sometimes but a single prominence may represent the coalesced external normal pair of cusps, all of the cusps being drawn out into sharp points suitable for cracking the hard coats of insects, and constituting the typical insectivorous type of molar as seen in the Mole and Bat, and also in the Insectivorous Marsupials, *Perameles*.

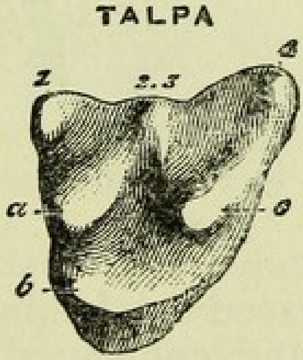

FIG. 238.—GRINDING SURFACE OF UPPER MOLAR OF LEFT SIDE.
a, *b*, and *c*, principal cusps; 1, 2, 3, and 4, cusps of cingulum.

A singular modification may be presented by the squeezing together, as it were, from behind forwards of the tooth till it forms but a single prism, and is therefore like half of one of the teeth last described. Such a condition exists in *Centetes*, *Hemicentetes*, and especially in *Chrysochloris*.

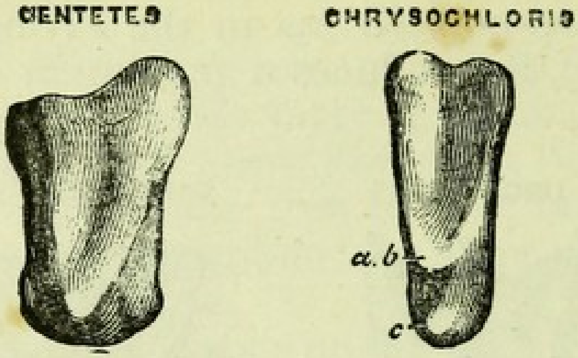

FIG. 239.—GRINDING SURFACES OF UPPER MOLARS OF LEFT SIDE.
a, *b*, and *c*, remnants of principal cusps.

Another kind of modification of the teeth is that by which the typically carnivorous molar is arrived at. This is best exemplified by the last pre-molar, which in the Dogs, Cats, and their allies has been called the "sectorial" or "carnassial" tooth of the upper jaw.

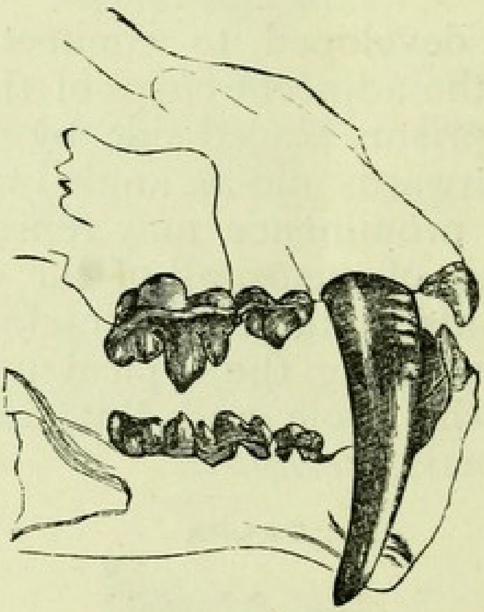

FIG. 240.—DENTITION OF THE SABRE-TOOTHED TIGER (*Machairodus*).
(TYPICAL CARNIVOROUS DENTITION.)

Here (in the Cats) it consists almost entirely of three sharp, strong, unequal cusps placed one behind the other on the outer margin of the tooth, and connected together by trenchant ridges, while inside the foremost cusp is a small, short, and blunt accessory one. From a study of Marsupial teeth it appears that the three outer cusps answer to the cusps of the cingulum blended with the two outer principal cusps of man, while the rudimentary internal cusp is the representative of the front, inner cusp of man—the hind inner one having disappeared.

In the true molars of the Dog this last cusp reappears, and in addition we find a large prominence of the internal part of the cingulum. In the Badger this latter structure is very much developed, extending in a marked manner along the

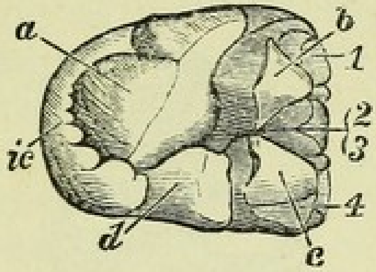

FIG. 241.—GRINDING SURFACE OF FIRST RIGHT UPPER MOLAR TOOTH OF *Ailurus fulgens*.

1, 2, 3, and 4, cusps of the external cingulum; *ic*, internal cingulum; *a*, *b*, *c*, and *d*, the four principal cusps.

whole inner margin of the tooth. In *Ailurus* we have a good example of the maximum of complexity of the carnivorous type of molar. We find in the molar of this animal four principal cusps, with three cusps belonging to the external cingulum, and two belonging to the internal cingulum.

Returning now to the type of structure exhibited by man's upper molar, we may follow through another series of animals yet a new chain of modifications, resulting in a very different kind of complication.

First, one transverse ridge may connect the two posterior

MACROSCELIDES

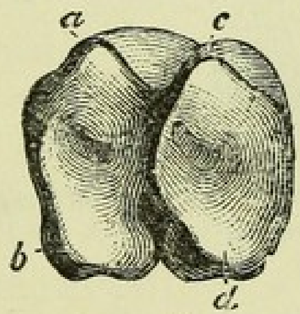

FIG. 242.—GRINDING SURFACE OF LEFT UPPER MOLAR, showing the transverse ridges (convex forwards) which connect together the anterior and posterior pairs of principal cusps respectively; *a*, *b*, *c*, and *d*, the four principal cusps.

cusps, and another may similarly unite the two anterior cusps. We see this in the Kangaroo and *Macroscelides*.

Next, a ridge may run along the external margin of the tooth (probably the cingulum) and connect together the two outer ends of these two transverse ridges. We find such a structure in the Tapir.

In the Rhinoceros, Horse, and the Ruminants, the essential structure of the Tapir's tooth persists, but is modified by greater and greater obliquity of the transverse ridges and by the development of supplementary processes running more or less at right angles to the transverse ridges.

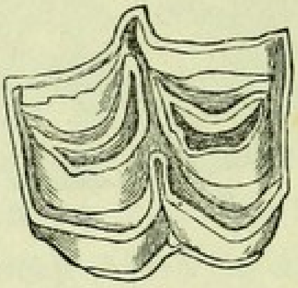

FIG. 243.—GRINDING SURFACE OF SECOND UPPER MOLAR OF A CAMEL, showing the double crescentic folds which have their convexities turned inwards.

In the Ruminants the transverse ridges are so much inclined backwards and inwards, that they come to be almost parallel with the external wall, thus forming the well-known double crescents with a deep excavation between them seen in the molars of Sheep.

In the Horse this excavation is filled up with "cement," and the pattern is complicated by the development of accessory processes from the convex, or inner side of the transverse ridges.

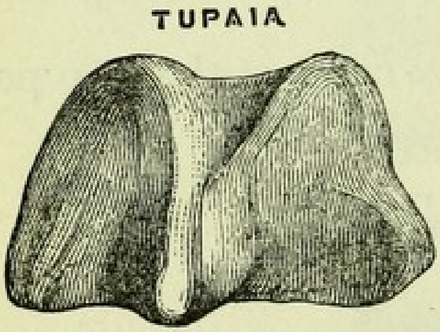

FIG. 244.—GRINDING SURFACE OF RIGHT LOWER MOLAR.

FIG. 245.—GRINDING SURFACE OF RIGHT LOWER MOLAR.

In the lower jaw an analogous series of modifications has similar results. In the insectivorous type these modifications result in a pair of triangular prisms (produced by the connection by ridges of the five cusps answering to the five cusps developed in the lower molar of man) ending in sharp points, as in the Mole; or in a single prism, as in the Golden Mole, *Chrysochloris*. The prisms are reversed in position as compared with those of the upper jaw. In the carnivorous type modification results in a "sectorial" tooth (here, *i.e.* in the lower jaw, a true molar), which may, as in the Badger, have, in addition to man's five cusps, an anterior one and three small posterior ones; or only the extra one in front, as in the Dog; or finally, as in the Cat, this tooth may attain its typical perfection. It does so by becoming, as it were, a cutting blade, consisting of but two sharp cusps connected by trenchant ridges, and biting against those of the upper sectorial tooth like one of the blades of a pair of scissors against the other. The posterior cusp seems to answer to the front outer cusp of man, and the anterior cusp to the extra anterior one of the Dog.

In the type of dentition culminating in the Horse, we start again from the transverse ridges of the Tapir; we find double crescents, as in the upper jaw, but with the direction of their convexities reversed, in the Ox and Sheep tribe; while in the Horse we find a similar reversal, and the extra processes springing from the concave aspect of the crescents.

Other and different complexities of form, as in the Elephant, will come more conveniently under the head of "Structure."

31. Below Mammals we meet with great varieties of form. Thus, in certain Fishes (*e.g.* the Chetodons) the teeth are like slender bristles. In the Efts the slender denticles terminate in two points, and in three in the Fish *Platax*.

In Lizards the teeth sometimes have serrated edges, as in the Iguana; sometimes they are rounded, blunt, and crushing.

In Fishes we may meet with every variety of shape, and sometimes, amongst the Sharks and Rays, a very great variety in the same mouth.

Teeth are sometimes excessively sharp and pointed, as in *Lamna* and *Odontaspis*; sometimes they are furnished with singular processes, as in *Goniadus*.

Sometimes, as in the Australian Shark *Cestracion*, the teeth in the front of the mouth are sharp and pointed, while as we pass backwards they become flattened till they form a sort of pavement to the jaws.

It is the Rays, however, which present us with the most wonderful pavement. In some of these Fishes (*e.g.* in *Myliobatis*) the teeth are placed in close contiguity, like the pieces of a mosaic, and, what is most remarkable, long and narrow teeth are placed in the middle line so as to cross the mandibular symphysis, or line of junction of the two jaws.

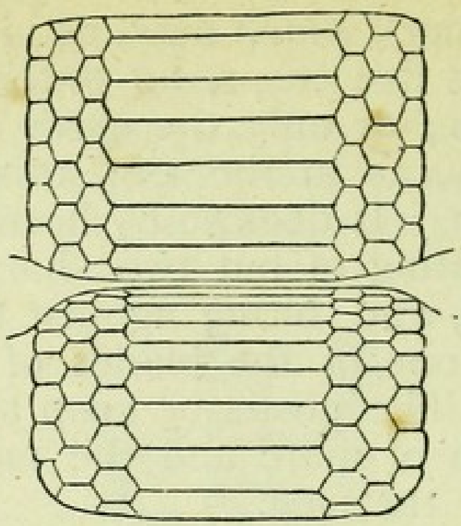

FIG. 246.—UPPER AND LOWER JAWS (SEEN FROM BEHIND) OF AN EAGLE RAY (*Myliobatis*), showing the elongated median dental plates and the hexagonal lateral plates.

One of the most singular modifications in the form of a tooth is presented by the poison-fangs of Serpents.

It is a common thing for a tooth to exhibit a vertical groove: we see it even in the canines of Apes; and in some extinct forms (e.g. *Ichthyosaurus*) the teeth were furnished with a number of such grooves.

In poisonous Serpents, however—*e.g.* the Rattlesnake—one large tooth on each side of the upper jaw has an exceedingly deep, vertical, anterior groove, the margins of which groove bend over till they meet and thus form a canal which opens

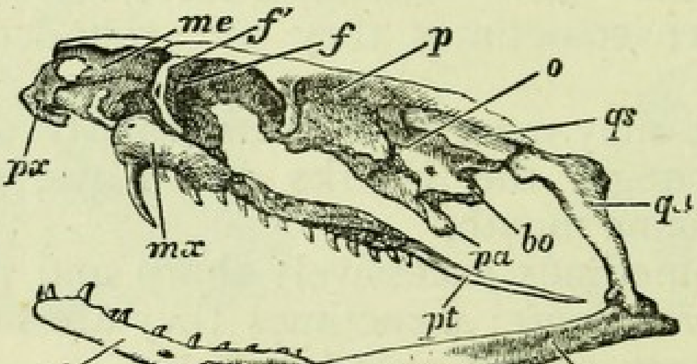

FIG. 247.—SIDE VIEW OF THE SKULL OF A RATTLESNAKE (*Crotalus*), showing the large poison-fang implanted in the maxilla—in front of the letters *mx*.

a, articular bone of lower jaw; *bo*, basi-occipital; *d*, dentary; *f*, frontal; *f'*, pre-frontal; *me*, median ethmoid; *mx*, maxilla; *o*, pro-otic; *p*, parietal; *pa*, para-sphenoid; *pt*, pterygoid; *px*, pre-maxilla; *qu*, quadrate; *qs*, squamosal.

widely above, but by a very small aperture below. It is down this channel that the poison is poured, the tube leading from the poison-gland opening into the upper part of the canal.

32. The SUCCESSION OF THE TEETH which we meet with in man is characteristic of most animals of his class, but not all. In many, as in the Guinea-pig, the so-called milk-

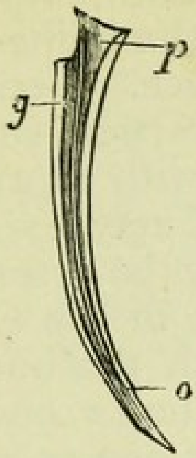

FIG. 248.—VERTICAL, LONGITUDINAL SECTION OF THE POISON-FANG OF A SERPENT. (*After Owen.*)

g, deep groove ; *o*, its lower termination, which affords exit to the poison ; *p*, pulp-cavity.

teeth are shed even before birth. On the other hand, they may be retained for a relatively longer period than they are

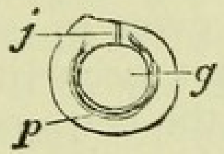

FIG 249.—MAGNIFIED TRANSVERSE SECTION OF A SERPENT'S POISON-FANG. (*After Owen.*)

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.

in man. Thus, in the Ungulates they persist till the adult form is reached, and, at least in some, till after the bony elements of the limb-girdles have completely coalesced.

Sometimes teeth are formed which are not destined to cut the gum, and are re-absorbed without ever becoming visible. This is the case with the upper incisor teeth of Ruminants. In the Whalebone Whales, before the development of baleen, minute teeth are developed in the dental groove, which teeth are ultimately absorbed while the groove itself becomes obliterated.

In the Marsupial Mammals but a single tooth is provided with a vertical predecessor. This tooth is the one which would be the fourth pre-molar were the normal number developed, and it thus serves to define the last of the pre-molars.

We see by this, that there may be teeth with no vertical predecessors in front of others which have such predecessors.

Milk-teeth may be entirely absent in some Mammals, as is the case in the Porpoises and Dolphins and most Edentates.

The canine teeth, as in the highest Apes, may appear after the true molars are in place. Generally the last deciduous molar resembles, not its vertical successor, but the first true molar, as has been stated with regard to man.

A mode of succession may exist in man's class which renders it difficult to define the essential nature of the anterior molars. Such is the case in the Elephant, where six teeth are successively developed, the hindmost ones being much more complex than the anterior ones. Each rotates into its position in such a way that one portion of it is worn before the last part is in place, and ultimately the whole of the jaw is occupied by a single tooth. The Elephant has, however, undoubtedly two upper deciduous incisors on each side, and three molars ought in all probability to be reckoned as deciduous ones on each side of each jaw.

Below Mammals we may find quite other conditions of replacement and succession; but though of course there is never a "milk" set, yet even in some Fishes there is a vertical succession like that occurring in Mammals. This, for example, is the case in the teeth of the front of the mouth of the Fish *Sargus*—which teeth, moreover, bear a singular resemblance to the incisors of man.

In the Crocodiles, as the teeth wear out or become lost, they are replaced by others, formed on the inner side of those which they are destined to succeed. Each new tooth causes, by its development, an absorption of the inner wall of an old tooth, and, entering at this aperture, it becomes enclosed within the central cavity of the latter, so that when the old tooth is removed the new one is found rising up in its place. This process appears to go on indefinitely through the whole of life in these creatures.

A far more abundant supply of new teeth and ready replacement of old ones are found in the Sharks. Whole rows of teeth, getting ready for use, lie folded back one behind the other all round the jaws. As the old teeth are lost, those immediately behind go forward, become erect, and take the vacant places.

The most singular succession of all is found in the Parrot Fishes (*Scarus*). Parrot Fishes browse upon those truly sensitive plants the arborescent polyps, and their jaws are singularly dense and hard, well suited for breaking up their stony prey. The jaws of the fish are shaped like a parrot's beak (whence its name); but it is a beak which singularly and interestingly differs in structure from that of a bird.

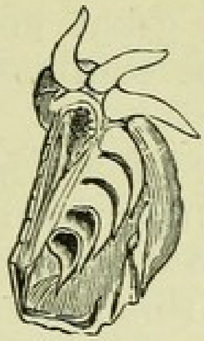

FIG. 250.—VERTICAL SECTION OF THE LOWER JAW OF A SHARK (*Lamna*), showing the uppermost erect tooth with the others below in various stages, each ready to come successively into place when its predecessor is removed. (*After Owen.*)

A bird's beak is, as we have seen, a modification of the epidermis. This fish-beak, however, is a truly enderonic structure, and calcareous, not horny. It is, in fact, formed of an immense number of small elongated teeth, which, closely packed side by side, are attached by their proximal ends to the surface of both the upper and lower beak-shaped jaws. As these jaws with the annexed denticles are worn away by use at their margins, both are replaced by a common down-growth of bone and teeth in the upper jaw, and by a common upgrowth of bone and teeth in the lower one.

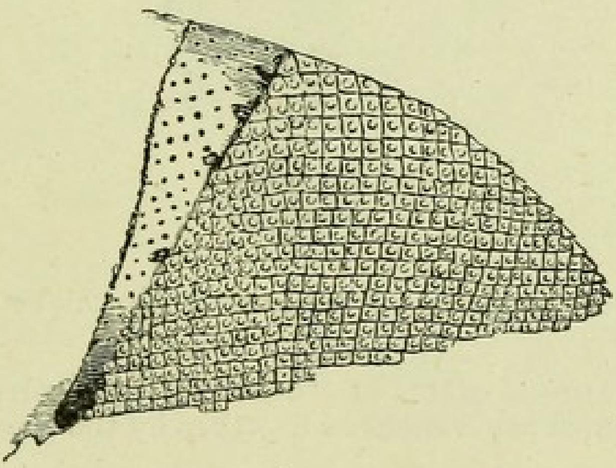

FIG. 251.—SIDE VIEW OF THE PRE-MAXILLA OF A PARROT-FISH (*Scarus*), showing the closely apposed denticles which encrust it. (*After Owen.*)

33. The STRUCTURE of man's teeth supplies us with a key by which we may understand that of Vertebrates generally; nor is there any real increase of complexity as to the number of the constituent materials, though the dentine may

be of various degrees of vascularity.[1] On the other hand, the structure of the teeth may be much simpler than in man in his own class, as, *e.g.*, in the Sloths and Armadillos, where the teeth are formed of dentine and cement only, being destitute of enamel.

The best example of great complexity of structure of a Mammalian tooth is that exhibited by one of the molars of the Indian Elephant.

Such a tooth consists of a number of narrow transverse plates of dentine, each plate being capped with enamel, and the interspaces between the plates being filled up with a quantity of cement, as if this material had been poured round and between the plates, and had there solidified. As the tooth wears, it assumes the transversely ridged appearance before noticed, which is an effect of the different densities of the component tissues.

Thus the enamel, being harder than either the dentine or the cement, stands up a little along each front and hind

FIG. 252.—GRINDING SURFACE OF LOWER MOLAR OF INDIAN ELEPHANT. (*After Owen.*)

d, *d*, two of the vertical plates of "dentine" (each surrounded by "enamel"), which are connected together by the "cement."

margin of each transverse plate; and in this way, proceeding from either end of the tooth along its grinding surface, we successively meet with layers thus arranged:— Cement, enamel, dentine, enamel, cement, enamel, dentine, enamel, cement, &c.

[1] *I.e.* may be more or less permeated by canals for nutritive fluid, which are larger than the dentinal tubes existing in man.

A similar but less extreme complexity of structure characterizes the last molar of the largest animal of the Rat order, namely, the so-called River-hog of the La Plata—*Hydrochœrus.*

Foldings of the dentine, bounded by enamel and with cement filling the valleys and interspaces, produce such complex patterns as we find in the Horse and Sheep already described, and also in the Porcupine and Beaver.

Molar teeth may grow (like those of man) from roots which soon become calcified, so that no more growth can take place; and this is the more common condition of the Mammalian molars.

They may have very long roots capable of a prolonged but still limited increase, as in the Horse.

They may spring from persistent roots growing during the whole of life, as in the Porcupine.

The pulp-cavity may be curiously disposed or divided. Thus in poisonous Serpents it extends round the greater part of the poison canal, which, it need hardly be said, is really outside the tooth. It may be divided transversely, as in the incisor of the Horse (Fig. 230), where one branch ascends in front of the depression (or "mark"), and the other branch ascends behind it. It may be divided antero-posteriorly, as in notched incisors, and especially in the comb-like ones of the Flying Lemur, where (Fig. 228) a branch of the pulp-cavity ascends each process of the "comb."

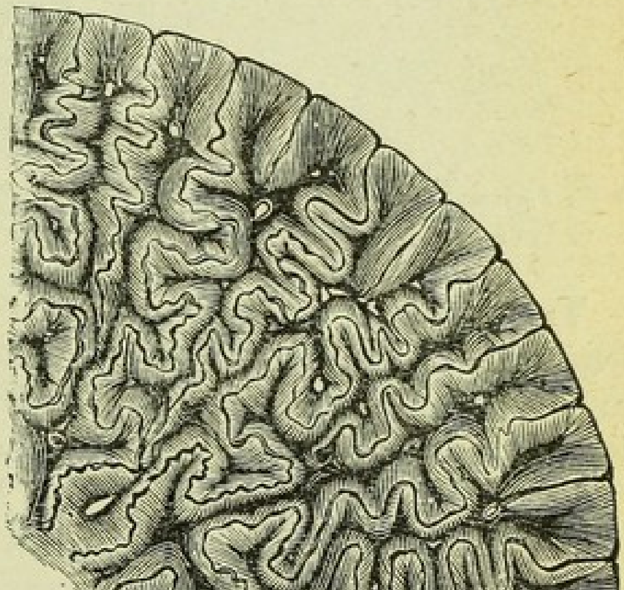

FIG. 253.—ONE QUARTER OF A MUCH ENLARGED HORIZONTAL SECTION OF THE TOOTH OF A LABYRINTHODON.

But the most remarkable form of the pulp-cavity is that which existed in those extinct Batrachians the Labyrinthodons. In those creatures, numerous vertical grooves on the surface penetrate with many inflections deeply into the substance of the teeth, and similar narrow processes of the pulp-cavity interdigitate, also with many inflections, between the inwardly extending grooves. With this structure a transverse section of the tooth presents such a complex series of radiating contorted lines as to have obtained for the animals their name, and for the kind of tooth the epithet Labyrinthic.

A third kind of complex tooth is presented by one Mammal only, though certain Fishes present a more or less similar structure. The animal referred to is the Cape Ant-eater (*Orycteropus*), which possesses the only *really compound* teeth found amongst Beasts.

FIG. 254.—THE AARDVARK, OR CAPE ANT-EATER. (*Orycteropus*).

Each tooth is cylindrical in shape, and apparently simple, but when cut transversely exhibits a number of minute apertures, as does a cut cane. Each of these apertures is the orifice of a pulp-cavity cut across, and from each of these cavities minute dentinal tubuli radiate in every direction, so that the tooth is really made up of a number of very elongated and slender denticles anchylosed together into one solid mass.

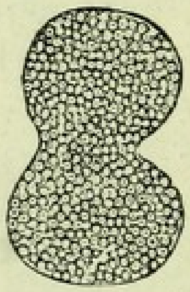

FIG. 255.—TRANSVERSE SECTION OF A TOOTH OF *Orycteropus*, showing the numerous denticles, each with its pulp-cavity.

True teeth do not co-exist with a horny beak in any known Mammal. They did so, however, in some of those extinct flying Reptiles the *Pterosauria*, and also the extinct Reptiles *Dicynodon* had a tooth which grew from a permanent pulp on each side of the head, though the jaws seem to have been furnished with a horny beak.

34. Enderonic calcifications which can hardly be called teeth may occur further back in the alimentary canal than anything we have yet met with. In a little African Serpent, *Rachiodon*, certain bony processes which depend from the ventral surface of the backbone penetrate the gullet and are tipped with a kind of enamel. These œsophageal[1] teeth per-

[1] Œsophagus is the name of the passage which leads from the back of the mouth (or pharynx) to the stomach.

form a peculiar function. The animal lives on eggs, but is devoid of lips, so that if it broke the eggs with its mouth their contents would be lost. It has then but rudimentary teeth in the ordinary place, but swallowing the eggs whole it fractures them with these œsophageal teeth, and thus loses none of the nutritive substance.

35. Structures which are quite like teeth—and indeed much resemble those of *Orycteropus*—project from either side of the very elongated rostrum which extends from the front of the head of the Saw-fish. These, then, are teeth quite external in position—enderonic dermal calcifications.

This, however, is not the only instance in which tooth-like structures appear on the external surface of the body. The Sharks and Rays, for example, have dermal calcifications (springing from a bony base) which consist of a substance exceedingly resembling dentine, and moreover coated with a sort of enamel. These may be quite small and thickly distributed all over the body. A skin so furnished is called *shagreen*. They may however be larger, fewer, and placed far apart, and as it were engraved with elegant patterns on the exposed surface, often forming powerfully defensive spines, as in some Sharks.

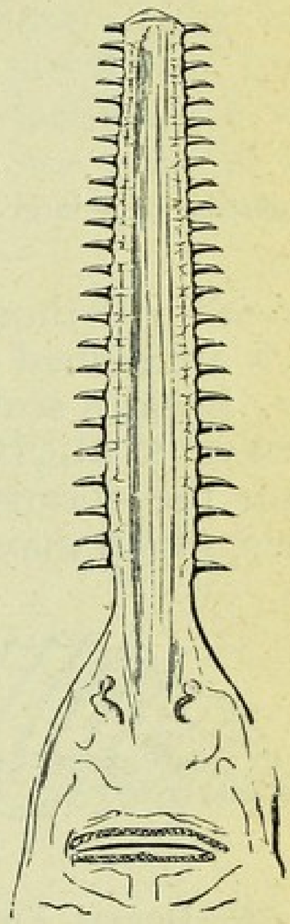

FIG 256.—UNDER SURFACE OF HEAD OF A SAW-FISH (*Pristis*), showing the large lateral teeth on the prolonged rostrum.

Other Fishes, as the Bony Pikes (*Lepidosteus*), have a close-fitting armour of solid, enamelled, bony scutes, which join together by means of a peg and socket articulation.

Fishes more familiar to us, but belonging to the same Ganoid group, *e.g.* the Sturgeon, are also furnished with bony scutes arranged in rows along the body.

The spines of some Teleostei present us with a peculiar kind of articulation—a *shackle-joint* (referred to in Lesson II.), the base of a spine forming a ring which passes through another ring developed from an ossicle supporting it (fig. 257).

36. The SCALES OF ORDINARY FISHES (as the Perch) are hard structures embedded in the deep layer, or dermis, and

so are quite unlike the scales of Reptiles. Indeed, the "scales" of Fishes should rather be termed "scutes."

They have been divided into two groups or kinds—those in which the free margin is smooth and which are termed

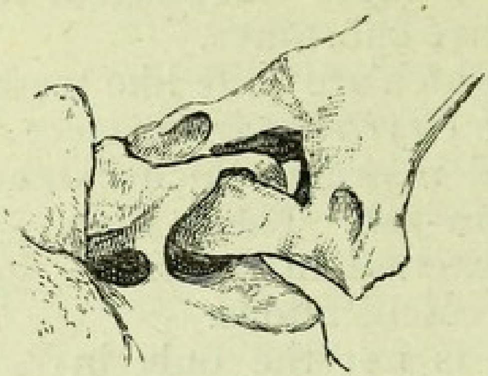

FIG. 257.—A SHACKLE-JOINT.
Articulation of a large spine with a bony plate (placed below) of the skin of a Siluroid Fish.

Cycloid,[1] and those in which the free margin is toothed and which are named *Ctenoid*.[2]

37. Besides scales, spines, and plates, Fishes have OTHER DERMAL STRUCTURES, bony or gristly, constantly present within the dermis. One kind consists of filamentary processes, which may be either horny or calcareous, and which

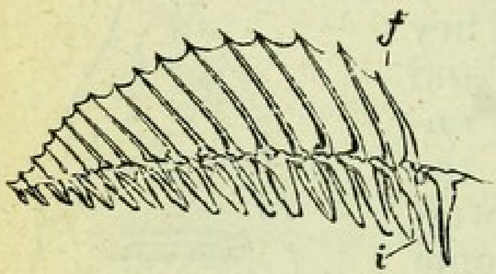

FIG. 258.—DORSAL FIN OF AN ACANTHOPTERYGIAN FISH, showing the firm, spiny fin-rays, *f*, supported on the inter-spinous bones, *i*.

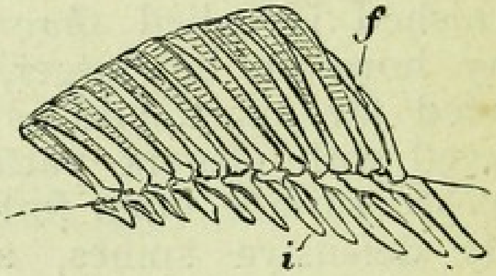

FIG. 259.—DORSAL FIN OF A MALACOPTERYGIAN FISH, showing the soft and sub-divided fin-rays, *f*, supported on the inter-spinous bones, *i*.

support the skin of the fins, whether those of the back, belly, and tail, or those of the limbs. Such structures are termed fin-rays. Another kind consists of the parts (bony or gristly) which support the fin-rays, and which are termed the "*inter-spinous*" bones or cartilages. These may be seen in the common Sole in the form of small bones extending along each margin of the body beyond the ends of the neurapophysial and hypapophysial processes which respectively project in opposite directions from the centre of the backbone.

[1] From κύκλος, a circle, and εἶδος, form.
[2] From κτείς, a comb, and εἶδος.

38. Lastly may be noticed certain exceptional though not unfamiliar structures which come perhaps more conveniently under the head of the exo-skeleton than elsewhere—namely, the BONY HORNS OF UNGULATES. In the Oxen, Goats, and their allies, horns exist on the head as bony cores persisting throughout life, and supporting the hollow horns before noticed under the head of "Epidermal Structures." In the Giraffe we meet with three bony prominences which arise as distinct ossifications, and only later anchylose with the skull. These are the pair of short "horns" and the median prominence in front of them. They are without doubt exoskeletal structures. In Deer, however, we meet with bony *antlers* which are shed annually and are destitute of any horny covering. These may exist in both sexes, as in the Reindeer, but generally in the males only. They arise as

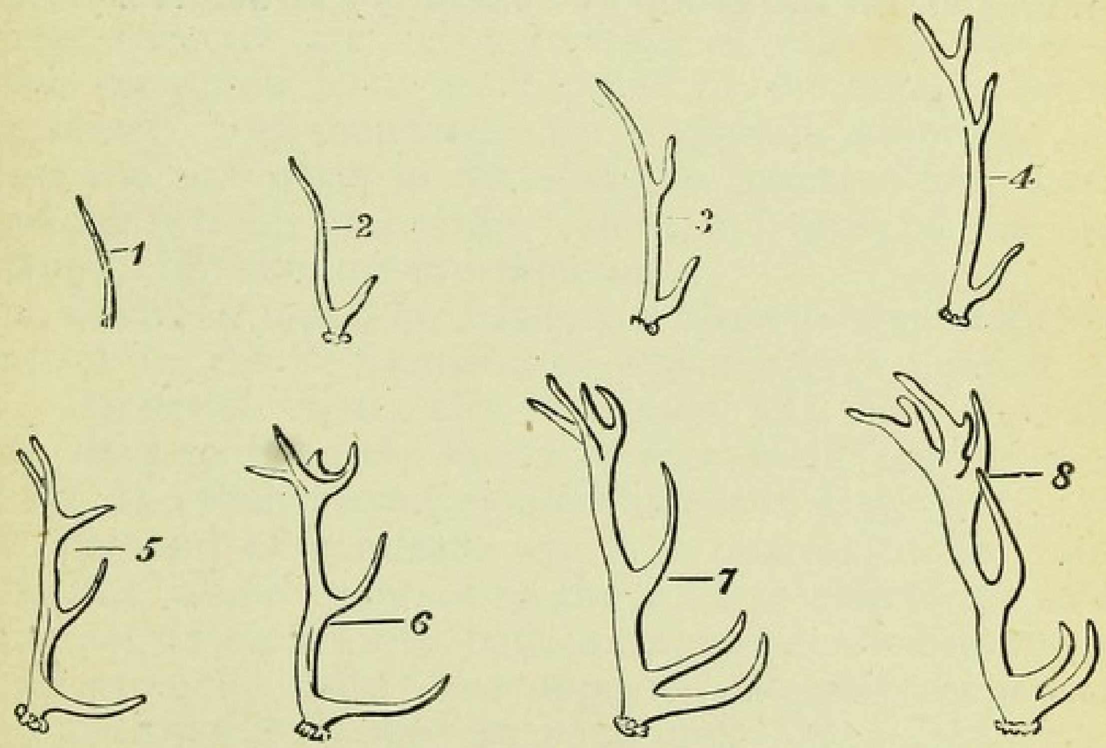

FIG. 260.—SERIES OF ANTLERS OF THE COMMON STAG, showing (from No. 1 to No. 8) the gradual increase (with age) of size and complexity in the antlers developed.

No. 1, the antlers which fall in the second year; 6, antler of a young "stag of ten;" 7 and 8, antlers of seven years old and upwards.

soft, highly vascular prominences, and when full grown become hardened by calcareous deposit. In some months the investing skin dries up and is rubbed away, and the horn itself falls off after the breeding season, leaving a stump, whence it shoots again in the following year.

Antlers, as a rule, are branched—more so as the individual is older till maturity be attained.

Some Deer have enormous antlers, weighing as much as seventy pounds, and are formed at the rate of one pound a day.

Great as must be the strain on the system from such a demand, it must yet be exceeded by the effects on Birds of the production of an entire new plumage when moulting.

The antlers, like the bony cores of the hollow-horned ruminants, are rather outgrowths from the skull than skin structures. Yet in the Giraffe we find short bony horns formed from ossifications independent of the skull, with which they unite at a later period only.

Such are the principal structures which may be described under the head of exo-skeleton. Other appendages of the skin which are not skeletal, but excretory (as the milk glands, scent glands), will be noticed in the Twelfth Lesson as coming within the group of "excretory structures."

LESSON VIII.

THE MUSCLES.

1. The MUSCLES of man are his "flesh," and it is the muscles of cattle which are eaten as "the lean" of "meat."

These muscles are fleshy masses of different sizes and shapes, separated from each other by membranes termed *aponeuroses*. Aponeuroses are included amongst those fibrous and soft parts of the skeleton (referred to in Lesson II.) which extend outwards from the bones of the endo-skeleton to the skin, or exo-skeleton.

The nature of muscular tissue has already been sufficiently described in the "Elementary Physiology," Lesson XII. § 15; the action of muscles in Lesson VII. § 4; their fixed points, §§ 5 and 6; the kinds of movement they give rise to, § 17; and their modes of attachment in § 19.

2. That end of a muscle which is nearest to the central axis of the whole body, or to the root, or else to the axis of the limb of which it forms part, is generally called its ORIGIN, and its proximal end. The opposite extremity is generally called its INSERTION, and its distal end.

Muscles are very often inserted into bones by means of tendons, and then frequently, when such muscles are strong, part of the bone extends out, as it were, a little way into the substance of the tendons. Hence arise many such tuberosities, spinous processes, &c., as we have already made acquaintance with. All the processes of the backbone are so connected with tendons of muscles.

3. Muscles acting on bony levers produce definite MOTIONS, in consequence of which certain epithets are applied to such muscles.

Thus, when two bones are united by a hinge-joint, 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*.

Some muscles attached to a long bone which is relatively fixed at one end, tend to make it describe the superficies of a cone, or a movement of *circumduction*. Such muscles are termed *rotators*.

Some muscles move a bone away from a given axis, and are therefore termed *abductors*. Others tend to bring it towards such an axis, and such are called *adductors*. The epithets "*protractors*," "*retractors*," "*elevators*," and "*depressors*" (terms which require no explanation), are also sometimes made use of.

There cannot, however, be any rational classification of muscles according to the functions they execute, because such functions often vary in different animals with regard to the very same muscle.

4. A sound CLASSIFICATION of muscles must be morphological, and may be made to follow that classification of parts which has been already given with respect to the skeleton, or may be constructed independently. An independent general consideration of the muscular system, however (whether according to its simplest or most complex condition), will come most fitly at the end of this lesson.

Arranging the muscles (in the first place) according to the skeleton, we have—

(*a*) Muscles of the exo-skeleton, and

(*b*) Muscles of the endo-skeleton.

To this it will be convenient to add a third category, namely—

(*c*) Muscles of the viscera.

The *exo-skeletal* system of muscles may consist of smooth or of striped fibres.[1]

Such are the small muscles which go from the deep layer of the skin to the hair-sacs, and by their contraction make the hair "stand on end." These muscles become large and important in Birds, and are in them striped instead of unstriped as in Man.

Other muscles, to be hereafter noted, belong to this category, such as the *Platysma Myoides*, and certain muscles of the face of man.

The *endo-skeletal* system is naturally divisible, like the skeleton itself, into an axial and appendicular portion. These

[1] For an account of this difference of structure in muscular fibres, see Lesson XII. of "Elementary Physiology," § 15.

general considerations, however, will be more profitable after a review of the muscles as they exist in man, and of the more interesting and significant deviations from his structure which may be found in other animals.

The *viscero-skeletal* system of muscles consists of muscular fibres placed on the walls of the alimentary canal, and in a variety of tubes and organs (such as the heart, bladder, &c.), to be hereafter noticed in describing such parts.

5. It may be useful and convenient in this book to adopt the order usually followed in describing man's anatomy. The MUSCLES OF THE HEAD AND NECK will therefore come first.

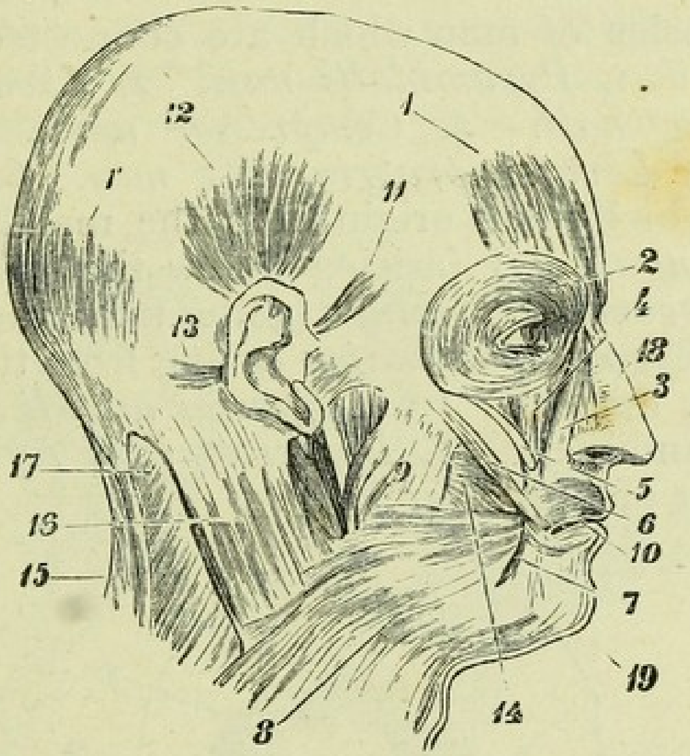

FIG. 261.—SUPERFICIAL MUSCLES OF THE HEAD: RIGHT SIDE.

1, anterior part of occipito-frontalis; 1', its posterior portion; 2, orbicularis palpebrarum; 3, levator labii superioris et alæ nasi; 4, levator labii superioris; 5, zygomaticus minor; 6, zygomaticus major; 7, depressor anguli oris; 8, platysma myoides; 9, masseter; 10, orbicularis oris; 11, anterior auricular; 12, attollens auriculam, or superior auricular; 13, retrahentes auriculam; 14, buccinator; 15, trapezius; 16, sterno-mastoid; 17, splenius; 18, transversalis nasi; 19, levator menti.

Occipito-frontalis is the name applied to a thin flat muscle, divided into two fleshy parts, or bellies. One of these is placed in the occiput and another over the orbits, and the two are connected by a wide aponeurosis which covers the top of the skull and passes immediately beneath the skin.

Three little muscles, termed respectively the *attollens* *auriculam*, the *retrahentes auriculam*, and the *zygomato-auricularis*, arise from above, behind, and in front of the ear, to the external part of which they are attached. In rare cases a man is able to move his ear by the contraction of these muscles.

The *orbicularis palpebrarum* is a muscle which surrounds the eye beneath the skin, and is not attached to any bone except at the inner margin of the orbit. By its contraction it closes the eyelids.

A little muscle, the *levator palpebræ*, takes origin deep in the orbit (above the optic foramen), and is inserted into the upper eyelid, which it raises. No analogous muscle depresses the lower eyelid.

Other muscles of man which are connected with the lips or nose are :—1. *Pyramidalis nasi.* 2. *Levator labii superioris alæque nasi.* 3. *Compressor naris.* 4. *Depressor alæ nasi.* 5. *Levator proprius alæ nasi.* 6. *Levator labii superioris* (which takes origin from the maxilla and malar). 7. *Levator anguli oris* (arising below the infra-orbital foramen). 8. *Zygomaticus minor* (going from the malar to join No. 6). 9. *Zygomaticus major* (going from the malar to the angle of the mouth). 10. *Depressor anguli oris* (springing from the mandible). 11. *Depressor labii inferioris* (placed near the front of the lower jaw.

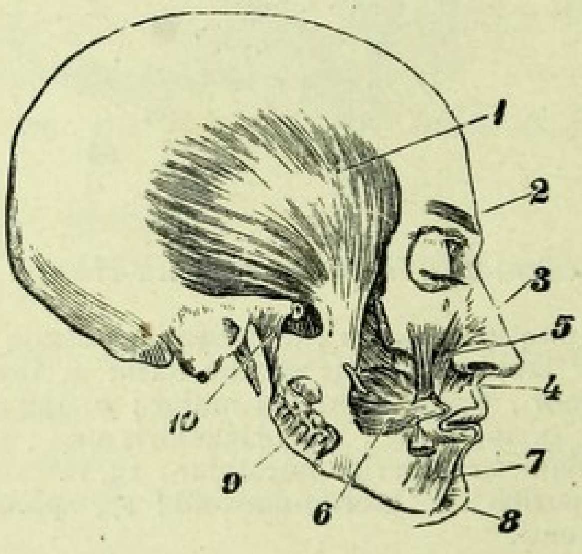

FIG. 262.—DEEPER MUSCLES OF THE RIGHT SIDE OF THE HEAD.

1, temporal ; 2, corrugator supercilii ; 3, transversalis nasi ; 4, depressor alæ nasi ; 5, levator anguli oris ; 6, buccinator, traversed towards its hinder part by the duct of the parotid gland ; 7, depressor labii inferioris ; 8, levator menti ; 9, masseter, cut short near its insertion ; 10, external lateral ligament.

The *buccinator* is a thin flat muscle extending between the alveolar margins of the jaws on each side.

The *orbicularis oris* is a muscle surrounding the aperture of the mouth.

The *masseter* passes from the malar down to the angle of the lower jaw.

The *temporalis* occupies the side of the skull within the zygoma, and is inserted into the coronoid process of the mandible.

The *pterygoideus internus* passes from the pterygoid fossa to the inner surface of the mandible just above its angle.

The *pterygoideus externus* arises from the ali-sphenoid (including the part called "external pterygoid process"), and is inserted into the neck of the condyle of the lower jaw and into the inter-articular fibro-cartilage.

Inside the bony orbit, we have four slender, long, straight muscles (or *recti*), and two oblique muscles, all inserted into the sclerotic, or outer coat of the globe of the eye.

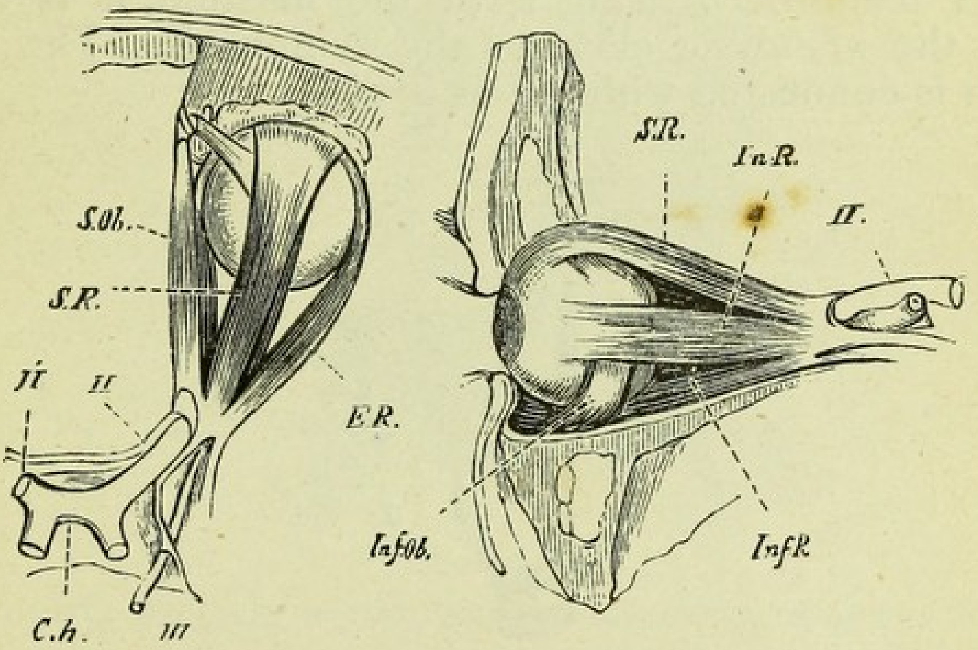

FIG. 263.—THE MUSCLES OF THE EYEBALL, viewed from above and from the outer side.

S.R., 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.

The four recti all arise at the bottom of the orbit, about the optic foramen, and are respectively inserted into the eyeball above, within, below, and without, whence they are termed *superior*, *internus*, *inferior*, and *externus*.

The *obliquus superior* (a slender muscle, like each of the recti) also arises near the optic foramen. At the inner margin of the orbit it passes through a fibro-cartilaginous ring or pulley, which changes the direction of the tendon, as, after traversing it, the tendon returns backwards to be inserted between the upper and external recti muscles.

The *obliquus inferior* has no pulley, and is the only short muscle in the orbit. It springs from the orbital plate of the maxilla near the lachrymal groove, and, passing backwards between the floor of the orbit and the globe of the eye, is inserted into the postero-external aspect of the latter.

The *platysma myoides* is a thin muscle placed immediately beneath the skin of the neck, and extending from the mandible downwards to the chest and shoulders.

The *sterno-cleido mastoid* is a long stout muscular strap, double at its lower end and arising partly from the clavicle and partly from the sternum, and inserted into the mastoid process.

The *digastric* is a muscle with two fleshy bellies, with a median tendon. Arising from the mastoid, it is inserted inside the mandible close to the symphysis. The median tendon is connected with the os hyoides.

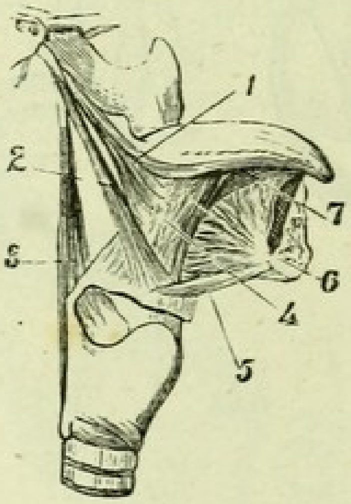

FIG. 264.—MUSCLES OF THE RIGHT SIDE OF THE TONGUE.

1, stylo-glossus; 2, stylo-hyoid; 3, stylo-pharyngeus; 4, hyo-glossus; 5, genio-hyoid; 6, genio-glossus; 7, lingualis.

The *stylo-hyoid*, *stylo-glossus*, and *stylo-pharyngeus* are three slender muscles all springing from the styloid process, and inserted, the first into the corniculum of the hyoid, the second into the base of the tongue, and the third into the thyroid cartilage of the larynx.[1]

The *mylo-hyoid* is a flat muscle, and passes from inside the mandible to the body of the hyoid. It unites with its fellow

[1] For a description of the larynx see Lesson XII.

of the opposite side (in front in the middle line) and the two together form the muscular floor of the mouth.

The *genio-hyoid* is narrow, and goes from the hyoid to the mandible inside the symphysis.

The *hyoglossus* is a flat muscle, passing from the cornua of the hyoid upwards to the side of the tongue.

The *genio-hyoglossus* is a flat, triangular fasciculus, arising inside the symphysis of the mandible, and inserted in a radiating manner from beneath the front of the tongue backwards to the body of the hyoid.

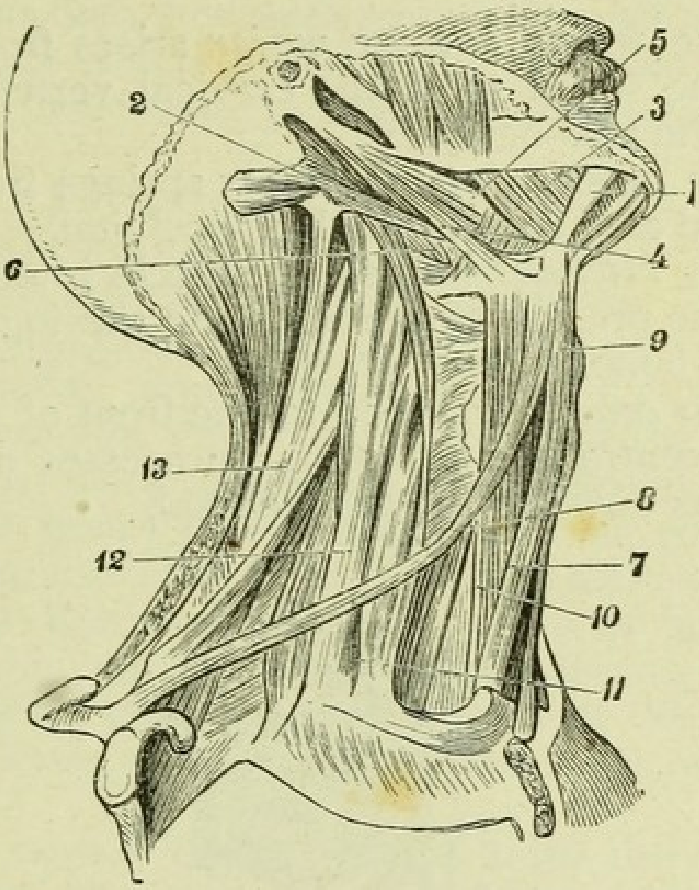

FIG. 265.—MUSCLES OF THE FRONT AND RIGHT SIDE OF THE NECK.

1, anterior belly of digastric ; 2, its posterior belly ; 3, mylo-hyoid ; 4, stylo-hyoid ; 5, stylo-glossus ; 6, stylo-pharyngeus ; 7, sterno-hyoid ; 8, omo-hyoid ; 9, thyro-hyoid ; 10, sterno-thyroid ; 11, anterior scalenus ; 12, middle scalenus—the posterior scalenus is seen immediately behind it arising from the second rib ; 13, levator anguli scapulæ.

The *sterno-hyoid* muscle is a long band which springs from within the sternum or clavicle, and goes to the basi-hyoid.

The *sterno-thyroid* (broader and shorter than the preceding) springs from within the sternum and goes to the thyroid cartilage of the larynx.

The *thyro-hyoid* appears like a continuation of the last-noticed muscle, and goes from the thyroid cartilage to the great cornua.

The *omo-hyoid* is a long digastric muscle which takes origin from the hyoid and is inserted into the upper margin of the scapula.

The *anterior scalenus* lies deep at the side of the neck. It springs from the parapophyses of the cervical vertebræ (third to sixth), and is inserted into the first rib.

The *middle scalenus* springs from the diapophyses of the cervical vertebræ, and also goes to the first rib.

The *posterior scalenus* arises from the diapophyses of the last two or three cervical vertebræ, and is inserted into the second rib.

The *rectus capitis anticus major* arises from the parapophyses of the (third to sixth) cervical vertebræ, and is inserted into the basi-occipital.

The *rectus capitis anticus minor* springs from the side of the atlas, and also goes to the basi-occipital.

The *rectus lateralis* is a short muscle interposed between the transverse process of the atlas and the jugular process of the occipital bone.

The *longus colli* is attached to the front of the spine, connecting the centra and transverse processes of the vertebræ from the atlas down to the third dorsal.

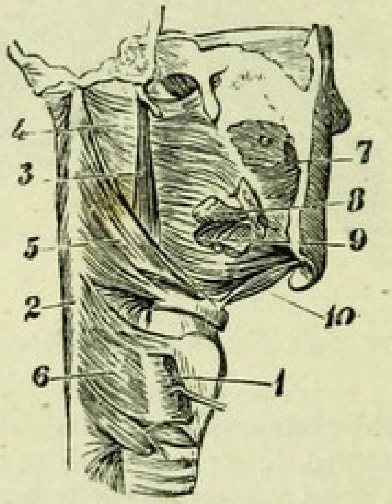

FIG. 266.—MUSCLES OF THE RIGHT HALF OF THE PHARYNX, seen from behind.

1, sterno-thyroid cut near its insertion and raised by a hook ; 2, median raphé, where the pharyngeal constrictor muscles of the right and left sides meet together behind ; 3, stylo-pharyngeus ; 4, superior constrictor of the pharynx ; 5, middle constrictor ; 6, inferior constrictor ; 7, buccinator ; 8, cut end of the stylo-glossus ; 9, cut end of the hyoglossus ; 10, genio-hyoid.

The constrictors of the pharynx are muscles which enclose the alimentary canal in the region of the throat : they are three in number (*inferior*, *middle*, and *superior*), and spring from the sides of the larynx, from the cornua and cornicula of the hyoid, from the lower jaw and pterygoids, and meet together in the middle line behind the pharynx, where, at their summit, they are attached to the basi-occipital.

The soft palate is formed with the help of five pairs of small muscles :—(1) the *levator palati*, descending from the petrous bone to meet its fellow of the opposite side, and also (2) the closely applied pair (miscalled *azygos uvulæ*) which descend vertically from the palate; (3) the *circumflexus palati*, going from the pterygoid to the palate; (4) the *palato-glossus*, descending from the uvula outwards to the wall of the throat; and (5) the *palato-pharyngeus*, arching downwards and backwards from the uvula so as to leave a gap between it and the palato-glossus.

6. The MUSCLES OF THE BACK are arranged in successive layers. Beginning with the most superficial of these, we find a large sheet of muscle called the *trapezius*. This arises from the occiput, the dorsal spinous processes, and the ligamentum nuchæ,[1] and is inserted into the spine of the scapula, the acromion, and the outer third of the clavicle.

The *latissimus dorsi* is a very large muscular sheet which arises from the spines of the sacral, lumbar, and six lowest dorsal vertebræ, and also from the ilium and some ribs. It converges to a narrow fasciculus, which is inserted, by a tendon, into the bicipital groove of the humerus.

The *rhomboideus* goes from the spines of the lower cervical and upper dorsal vertebræ to the vertebral border of the scapula.

The *levator anguli scapulæ* arises from the diapophyses of the first three or four cervical vertebræ, and goes to the postero-superior angle of the scapula.

The *serratus posticus superior* is a flat thin muscle which springs by aponeurosis from the spinous process of the two or three upper dorsal vertebræ and from the ligamentum nuchæ, and is inserted by fleshy digitations into the second, third, and fourth ribs.

The *serratus posticus inferior* similarly arises from the spines of the last two dorsal and three upper lumbar vertebræ, and is inserted (also by fleshy digitations) into the last four ribs.

[1] This structure consists of a band of tendinous fibres extending backwards from the cervical spinous processes, so as to form a partition between the neck-muscles of the two sides. It is attached above to the occiput, below to the spine of the seventh cervical vertebra.

The *splenius* is placed obliquely in the neck, extending from the spines of dorsal and cervical vertebræ to the transverse processes of the upper cervical vertebræ and to the mastoid process: the latter insertion defines the splenius *capitis;* the former the splenius *colli.*

Erector spinæ. Under this title is included a very large and complex muscular mass occupying the groove which exists on each side of the dorsum of the skeleton, between

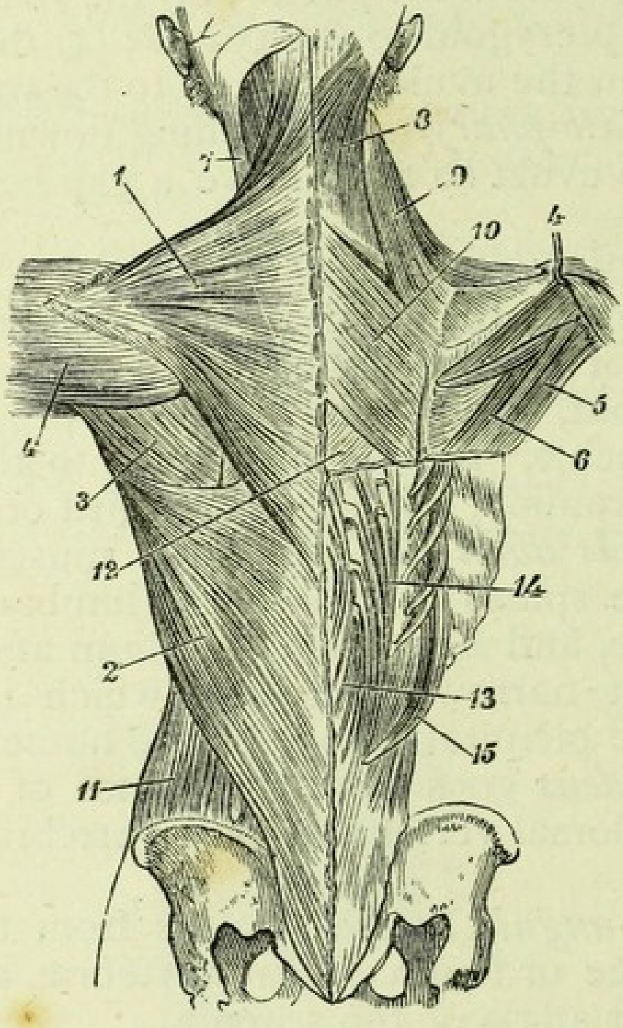

FIG. 267.—MUSCLES OF THE BACK.

On the left side the superficial muscles are shown. On the right side not only are these removed, but the serratus posticus inferior and abdominal muscles also, and the vertebral aponeurosis is cut short (below 12) to show the deepest muscles of the back.

1, trapezius; 2, latissimus dorsi; 3, infra-spinatus and teres; 4, deltoid—raised on the right side to show the infra-spinatus, (5) teres major, and (6) teres minor; 7, sterno-mastoid; 8, splenius; 9, levator anguli scapulæ; 10, rhomboideus; 11, external oblique; 12, vertebral aponeurosis (lying in the same plane with the serrati postici); 13, spinalis dorsi; 14, longissimus dorsi; 15, sacro-lumbalis.

the vertebral spinous processes and the most backwardly projecting parts of the ribs. In anthropotomy it is divided into a number of parts which here it will not be necessary to describe. Its main division will suffice, and this is twofold—one part being nearer to, the other further from, the vertebral spines; and each extending from a common origin in the sacral region upwards to the neck and head, where the parts assume distinct designations:—

Sacro-lumbalis. This name designates that part of the erector spinæ which is the more externally placed and attached to the ribs. Its uppermost continuation (which goes to the transverse processes of three or four cervical vertebræ) is called the *cervicalis ascendens*, or sometimes *descendens*.

Longissimus dorsi is the term applied to the inner part of the erector spinæ; it is attached to the transverse processes, the metapophyses, and the ribs within their angles. Its summit (going to the transverse processes of four or five cervical vertebræ) is called the *transversalis cervicis*.

Other minor subdivisions of the erector spinæ bear the names *spinalis*, *semi-spinalis*, *multifidus spinæ*, *rotatores spinæ*, and *interspinales*, the details of which will be found in ordinary works on Anthropotomy.

The *complexus* is a thick muscle going obliquely to the occiput from the diapophyses of the three uppermost dorsal and four lowermost cervical vertebræ. A small muscle passing from the spine of the axis to the occiput is called the *rectus capitis posticus major*, while the *rectus capitis posticus minor* (inserted below the last) springs from the neural arch of the atlas. The *obliqui capitis* pass respectively, the *inferior* from the spine of the axis to the transverse processes of the atlas—the *superior* from the latter to behind the mastoid processes.

Inter-transversales connect the transverse processes of adjacent vertebræ.

7. Of muscles of the upper extremity we have in front a large *pectoralis major*, the fibres of which, arising from the clavicle, sternum, and ribs, converge to be inserted into the bicipital groove of the humerus. We have also a *pectoralis minor*, which goes from the third, fourth, and fifth ribs to the coracoid process.

The *subclavius* is a small muscle placed as its name implies, and extending from the cartilage of the first rib to the under surface of the clavicle.

A muscle called the *serratus magnus* is really but an inferior portion of the levator anguli scapulæ before described. It arises by pointed digitations from eight ribs, and is inserted into the base (or vertebral border) of the scapula.

The *deltoid* is triangular in outline, and covers over the shoulder-joint. Springing from the clavicle and the spine of the scapula, it is inserted into the rough prominence on the outer side of the shaft of the humerus.

Supra-spinatus. This name is given to the muscle which occupies the supra-spinous fossa of the scapula. It is inserted into the greater tuberosity of the humerus.

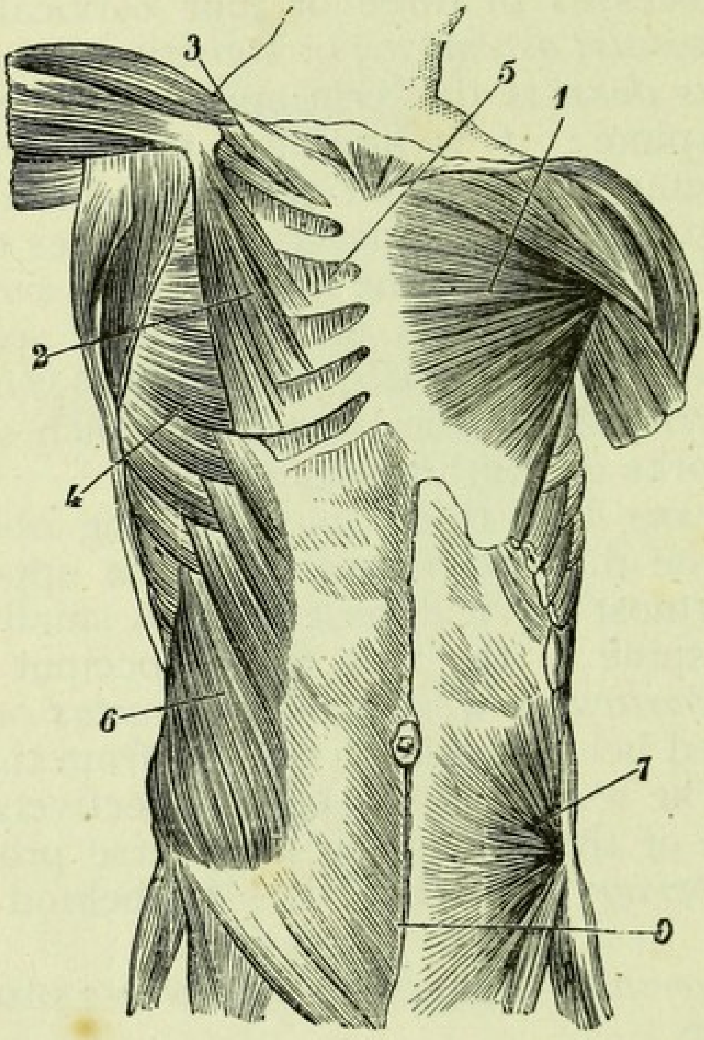

FIG. 268.—ANTERIOR MUSCLES OF THE TRUNK—the pectoralis major of the right side and the left external oblique being removed.

1, pectoralis major; 2, pectoralis minor; 3, subclavius; 4, serratus magnus; 5, internal intercostals; 6, external oblique; 7, internal oblique; 8, linea alba.

The *infra-spinatus,* also named from its origin, is also inserted into the same tuberosity.

The *teres minor* is a small muscle inserted like the two preceding, and arising from the axillary border of the scapula. The *teres major* goes from the inferior angle of the scapula to the lesser tuberosity, which also gives insertion to the large *subscapularis* muscle arising from the fossa of the scapula on its inner surface.

The *coraco-brachialis,* small and inconspicuous, springs from the coracoid process, and is inserted on the inner side of the humerus.

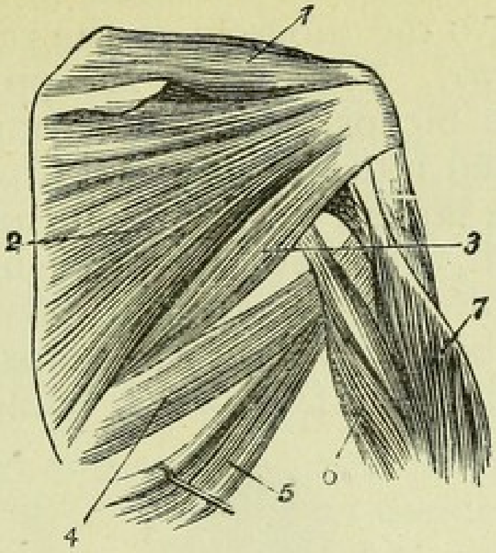

FIG. 269.—MUSCLES OF THE RIGHT SHOULDER-BLADE, viewed from behind.

1, supra-spinatus; 2, infra-spinatus; 3, teres minor; 4, teres major; 5, latissimus dorsi near its insertion; 6, scapular head of triceps; 7, external humeral head of triceps.

The *biceps* is the well-known muscle used in flexing the arm. It arises by two heads: one a long tendon from the

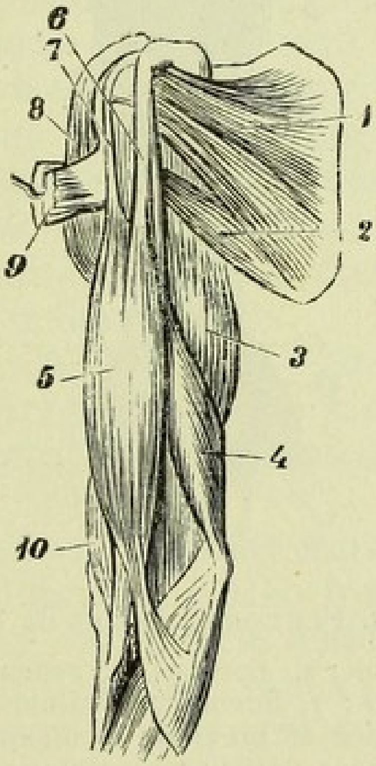

FIG. 270.—INNER ASPECT OF SUPERFICIAL MUSCLES OF RIGHT SHOULDER-BLADE AND UPPER ARM.

1, subscapularis; 2, teres major; 3, scapular part of triceps; 4, internal humeral part of triceps; 5, biceps; 6, coracoid head and tendon of biceps, on the inner side of which is a small muscle, the coraco-brachialis; 7, humeral head and tendon of biceps; 8, deltoid; 9, cut end of pectoralis major, supported by a hook, and shown to be folded on itself; 10, brachialis anticus.

margin of the glenoid cavity; the other, shorter, from the coracoid process. The muscle formed by the union of these heads is inserted into the tubercle of the radius.

Brachialis anticus. This term is applied to a muscle placed beneath the biceps, springing from the front of the humerus and inserted into the coronoid process of the ulna.

The *triceps* is the largest muscle of the arm, and is inserted into the olecranon. It arises by three heads: one (*long*) from the lower border of the glenoid cavity, one (*external*) from the humerus below the great tuberosity, one (*internal* or *short*) from the inner surface of the humerus.

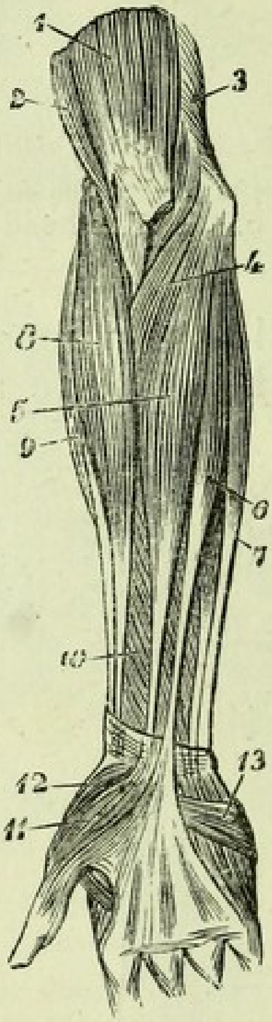

FIG. 271.—SUPERFICIAL FLEXOR MUSCLES OF RIGHT FORE-ARM.

1, biceps; 2, brachialis anticus; 3, triceps; 4, pronator teres; 5, flexor carpi radialis; 6, palmaris longus; 7, flexor carpi ulnaris; 8, supinator longus; 9, extensor carpi radialis longior et brevior; 10, flexor sublimis digitorum; 11, abductor pollicis; 12, opponens pollicis; 13, palmaris brevis.

8. The MUSCLES OF THE FORE-ARM consist of pronators and supinators, flexors and extensors.

Pronator teres. A muscle thus named rotates the fore-arm in the way described in the lesson on the bones of the arm under the name "pronation." It arises from the inner condyle of the humerus and from the coronoid process of the ulna, and proceeds obliquely across to the outer side of the radius.

The *flexor carpi radialis* arises from the inner condyle and is inserted by a tendon into the second metacarpal.

The *palmaris longus* also springs from the inner condyle, and ends in a fibrous expansion in the palm of the hand.

The *flexor carpi ulnaris* arises partly from the same condyle, partly from the olecranon (the ulnar nerve passing between these origins). It is inserted by tendon into the pisiform bone and the fifth metacarpal.

The *flexor sublimis digitorum* is (as its name implies) the superficial bender of the fingers. It takes origin from the inner condyle, the coronoid process of the ulna, and part of the front surface of the radius. It divides near the wrist into four tendons, which go respectively to the second phalanx of each of the four digits. Each tendon splits (before it is inserted) to allow a tendon of the deep flexor tendon to pass through it—whence the superficial flexor is also called the *perforatus.*

The *flexor profundus digitorum* or *perforans* arises from the ulna and from the membrane connecting that bone with the radius. Above the wrist it gives rise to four tendons which are respectively inserted into the distal phalanges of the four fingers, each tendon passing through the split before mentioned as existing in each tendon of the perforated flexor.

The *lumbricales* are small worm-like muscles (whence their name) which arise, in the hand, from the deep flexor tendons on their radial side, and are inserted into the same side of the respective four fingers.

Flexor longus pollicis is the name of a muscle which—arising from the fore part of the radius and being inserted by a long tendon into the last phalanx of the pollex—bends the thumb.

Pronator quaaratus. A short muscle thus named extends across from the radius to the ulna towards their distal ends.

Supinator longus. A muscle which antagonises the pronators, springs from above the external condyle of the humerus and is inserted into the outer border of the distal end of the radius.

The *extensores carpi radialis longior* and *brevior* are two muscles which arise, one over the other, from above the external condyle of the humerus, and end each in a tendon ; the first being inserted into the second metacarpal, and the second tendon into the middle metacarpal.

The *anconeus* is a very small triangular muscle which goes from the outer condyle of the humerus to the radial aspect of the olecranon.

The *extensor communis digitorum* stretches the fingers. Springing from the fibrous membrane which invests its fleshy mass, and from the outer condyle, it divides into four tendons,

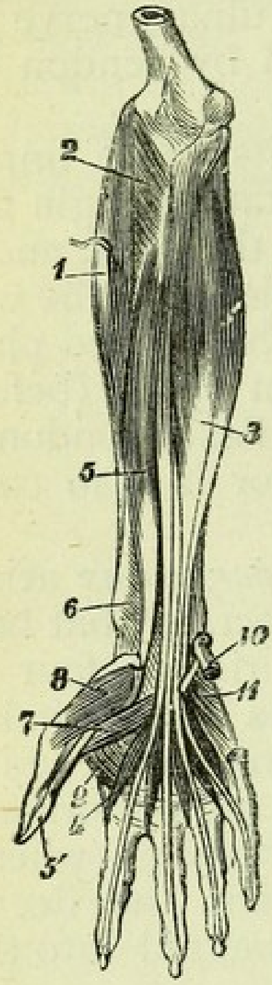

FIG. 272.—DEEPER FLEXOR MUSCLES OF RIGHT FORE-ARM.

1, extensor carpi radialis brevior; 2, supinator brevis; 3, flexor profundus digitorum; 4, one of the lumbricales; 5, flexor longus pollicis; 6, pronator quadratus; 7, flexor brevis pollicis; 8, opponens pollicis; 9, adductor pollicis; 10, origin of the adductor minimi digiti; 11, opponens digiti minimi.

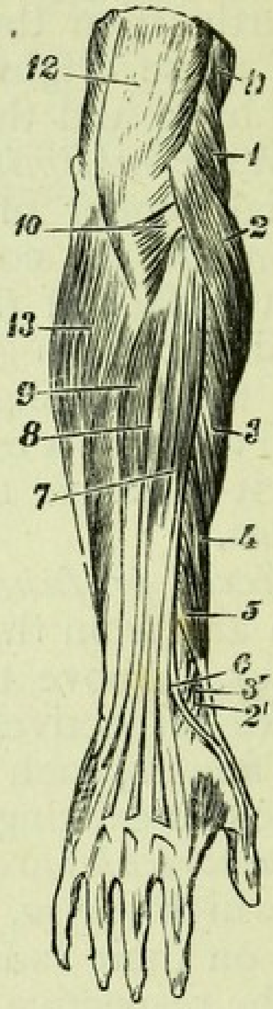

FIG. 273.—SUPERFICIAL EXTENSOR MUSCLES OF RIGHT FORE-ARM.

1, supinator longus; 2, extensor carpi radialis longior; 3, extensor carpi radialis brevior; 4, extensor ossis metacarpi pollicis; 5, extensor primi internodii pollicis; 6, extensor secundi internodii pollicis; 7, extensor communis digitorum; 8, extensor proprius digiti minimi; 9, extensor carpi ulnaris; 10, anconeus; 11, brachialis anticus; 12, triceps; 13, flexor carpi ulnaris.

which are respectively inserted into the second and last phalanges of each of the four fingers. A more or less separate part, sending an additional tendon to the fifth digit, is reckoned as a distinct muscle and called the *extensor minimi digiti.*

The *extensor carpi ulnaris* springs from the external condyle and from the ulna, and ends in a tendon going to the fifth metacarpal.

Extensor ossis metacarpi pollicis. This great stretcher of the thumb arises from both the ulna and radius (on their hinder aspect), and is inserted by a long tendon into the first metacarpal.

The *extensor primi internodii pollicis* is a small muscle which springs from the membrane between the radius and the ulna, and is inserted into the proximal phalanx of the thumb, as the *extensor secundi internodii* (springing from the back of the ulna) is inserted into its distal phalanx.

The *extensor indicis* is a narrow muscle which takes origin from the middle of the ulna behind, and is inserted into the posterior surface of the second and third phalanges of the index.

Supinator brevis. A deep muscle thus named comes from the outer condyle and upper part of the ulna, and is inserted into the radius wrapping it round somewhat from behind.

9. The MUSCLES OF THE HAND are numerous, but small. The thumb (which has no perforated flexor) is provided with a *flexor brevis* going from the carpus to the proximal phalanx; also an *abductor* from the trapezium to the proximal phalanx, and an *adductor* (placed in the fold of skin between the thumb and index digit), going to the same phalanx from the middle metacarpal. Besides these there is an *opponens*, which goes from the trapezium to the outer border of the first metacarpal.

The little finger has also an *opponens*, going from the unciforme to the fifth metacarpal; an *abductor*, from the pisiforme to the proximal phalanx; and a *flexor brevis*, from the unciforme to the same phalanx.

Small muscles called *interossei* arise from the sides of the metacarpals and go to the sides of the proximal phalanges. When the back of the hand (the other muscles being dissected off) is looked at, four (*dorsal*) interossei are seen; one going to each side of the middle digit, one to the radial side of the index, and one to the ulnar side of the ring digit. When the palm of the hand is looked at, three (*palmar*) interossei are seen: one going to the ulnar side of the index digit, and two to the radial side of the fourth and fifth digits respectively.

10. The ABDOMINAL REGION of the body is invested by three great sheets of muscle and membrane. The first of these, the *external oblique* (Fig. 268, 6), springs from outside

the eight or nine lower ribs, and its fibres pass downwards and inwards (towards the mid-ventral line), being inserted by muscle and membrane into the brim of the pelvis, part dividing into what are called the "external" and "internal" tendons of the muscle. Above, this muscle is connected with the pectoralis major.

The deeper abdominal muscle, the *internal oblique*, is represented by membrane only in the mid-ventral region. It passes from the ilium and adjacent structures, up towards

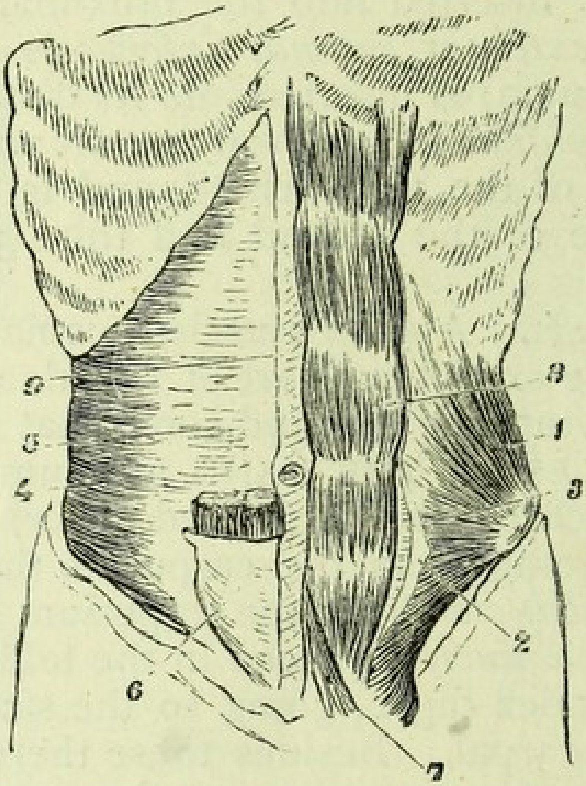

FIG. 274.—DEEPER ABDOMINAL MUSCLES—the external oblique being removed from the left side of the body, and the internal oblique and part of the rectus also, from its right side.

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 fascia; 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*.

the cartilages of the ribs, its fibres mostly proceeding in the reverse direction to those of the muscle last described.

The deepest of the abdominal muscles, the *transversalis*, springs from the ilium and lower ribs, and its fibres, proceeding horizontally, end in an aponeurosis, which meets its fellow in the mid-ventral line. The abdominal nerves extend round the body between this muscle and the internal oblique.

Rectus abdominis. This is a long muscle which, springing from the pubis, ascends to the cartilages of the fifth, sixth, and seventh ribs. The rectus is separated from its fellow of the other side only by a narrow interval which is occupied by a tendinous cord—the *linea alba.*

The fibres of the rectus are interrupted at intervals by transverse tendinous intersections.

A small *pyramidalis* muscle arises on each side of the pelvis, and extends from the pubis to the *linea alba.*

Quadratus lumborum. This is a mass of muscle situate close to the vertebral column, and extending upwards from the ilium to the last rib.

Layers of fibres between adjacent ribs are called the *external* and *internal intercostal* muscles. The former extend from the tubercles of the ribs to their cartilages. The latter extend from the sternum to the angles of the ribs. The intercostal nerves and vessels are interposed between them.

The *levatores costarum* are small groups of fibres passing obliquely downwards from the transverse processes to the respective ribs at their proximal parts.

Triangularis sterni is the name given to a layer of muscle which diverges upwards to the cartilages of the ribs from the deep surface of the lower part of the sternum.

11. The DIAPHRAGM is a very important muscle for respira-

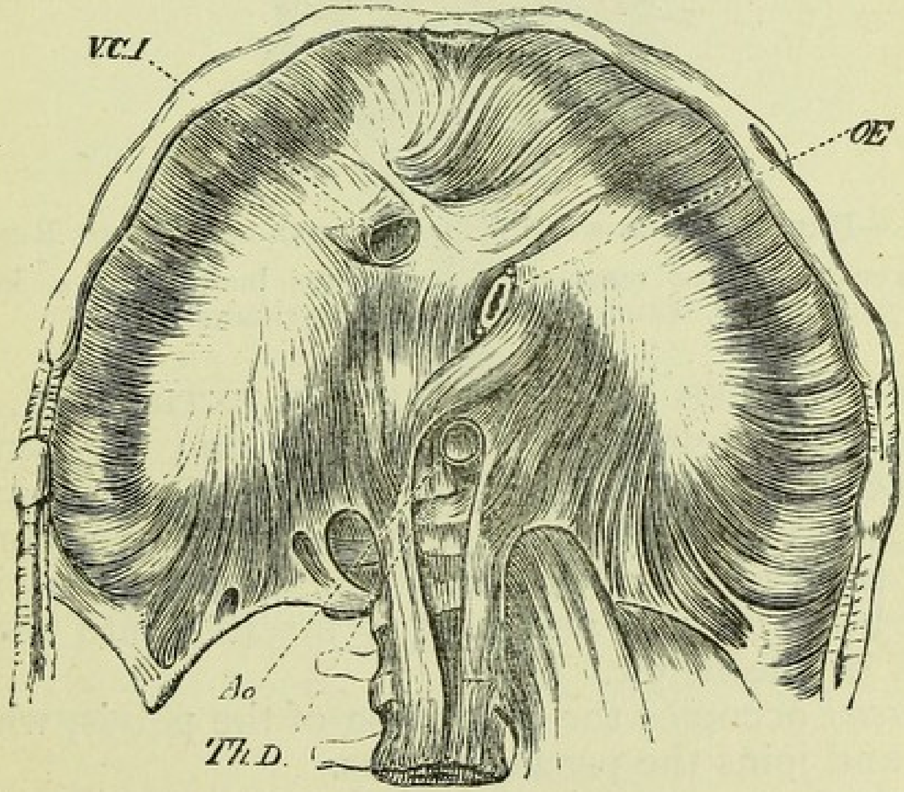

FIG. 275.—THE DIAPHRAGM, viewed from the lower or abdominal side.

V.C.I., the vena cava inferior ; *Œ*, the œsophagus ; *Ao*, the aorta ; *Th. D.*, the thoracic duct, cut where they pass through the diaphragm, the broad white tendinous middle of which is easily distinguished from the radiating muscular fibres which pass down to the ribs and into the pillars in front of the vertebræ.

tion, as explained in the Fourth Lesson of "Elementary Physiology." It is a partly fibrous, partly muscular partition between the thorax and abdomen, perforated for the passage of certain organs—namely, the œsophagus, or swallow, and two great blood-vessels named aorta and vena cava. The diaphragm is strongly convex upwards and concave downwards, and is attached to the ensiform cartilage and several ribs, to the centra of the lumbar vertebræ, and to fibrous structure binding down the quadratus lumborum and other muscles. Muscular towards its circumference, the diaphragm has a tendinous central portion.

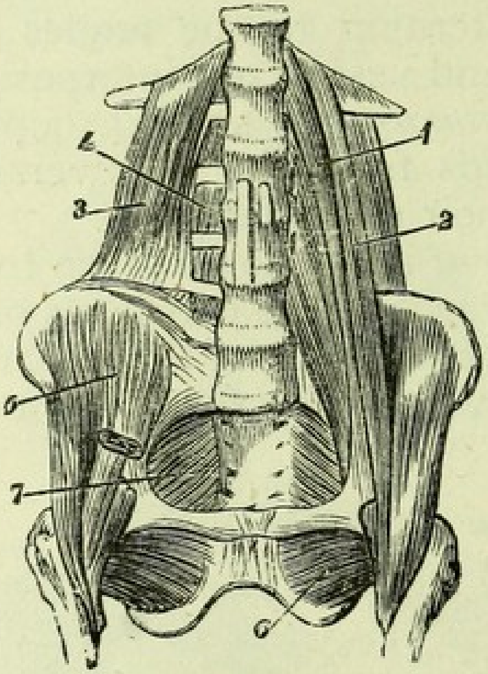

FIG. 276.—DEEP MUSCLES WITHIN THE LUMBAR AND PELVIC REGIONS.

1, psoas parvus; 2, psoas magnus; 3, quadratus lumborum; 4, inter-transversarii; 5, iliacus; 6, obturator externus; 7, pyriformis.

12. The MUSCLES OF THE INFERIOR EXTREMITY, though mainly taking origin from the pelvis and leg-bones, yet partly arise from the loins. Thus the *psoas magnus* springs from the centra of the lumbar and last dorsal vertebræ, and from the transverse processes of the former. Passing out over the brim of the pelvis, it is inserted into the lesser trochanter of the femur.

The *iliacus* occupies the iliac fossa of the pelvis, whence it descends and joins the psoas magnus.

The *psoas parvus* springs from the bodies of the last dorsal and first lumbar vertebræ, and is inserted into the ilio-pectineal eminence.

The *gluteus maximus* is a very large muscular mass which arises from the posterior part of the crest of the ilium, the posterior part of the sacrum, posterior sacro-sciatic ligament, and coccyx. It is inserted into a rough line below the great trochanter.

The *gluteus medius* springs from outside the ilium, and is inserted into the great trochanter.

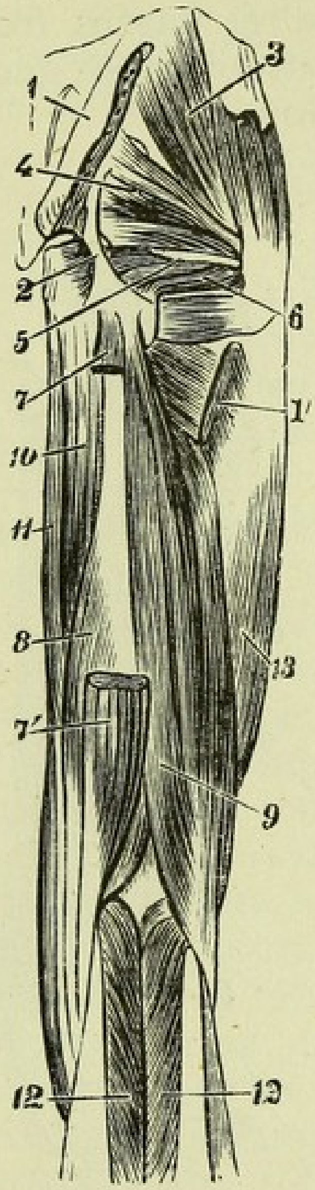

FIG. 277.—HIND VIEW OF THE MUSCLES OF THE PELVIS AND RIGHT THIGH—the gluteus maximus and semi-tendinosus being cut and removed.

1, origin of the gluteus maximus; 1', its insertion; 2, great sacro-sciatic ligament; 3, gluteus medius; 4, pyriformis; 5, tendon of obturator internus; 6, gemellus inferior (immediately below this, without a number, is the quadratus femoris); 7, origin of the semi-tendinosus; 7', its insertion; 8, semi-membranosus; 9, biceps femoris; 10, adductor; 11, gracilis; 12, 12, heads of the gastrocnemius; 13, vastus externus.

The *gluteus minimus* has a similar origin, but deeper, and a similar insertion.

The *pyriformis* arises from the front of the sacrum, and, passing out of the pelvis by the sacro-sciatic notch, is inserted into the great trochanter.

Muscles named *obturator internus* and *obturator externus* spring respectively from the inner and outer surfaces of the obturator membrane and ischium, and are inserted into the trochanteric fossa. Two little muscles (*gemelli*) arising respectively from the spine and tuberosity of the ischium, join the tendon of the internal obturator above and below.

The *quadratus femoris* passes from the tuberosity of the ischium to the great trochanter and to the surface of the femur immediately below it.

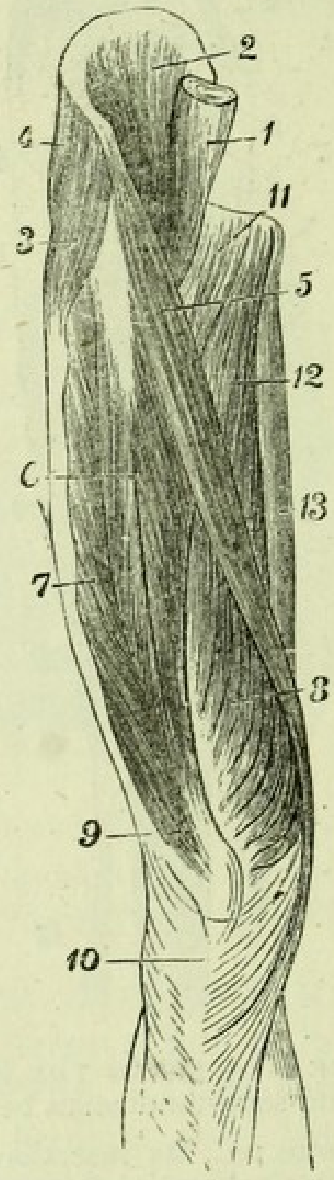

FIG 278.—ANTERIOR MUSCLES OF THE RIGHT THIGH

1, psoas magnus; 2, iliacus; 3, tensor vaginæ femoris; 4, gluteus medius: 5, sartorius; 6, rectus femoris; 7, vastus externus; 8, vastus internus; 9, points to the junction of the extensor muscles near their insertion into the patella; 10, aponeurosis of the knee; 11, pectineus; 12, adductor; 13, gracilis.

A muscle called the *tensor vaginæ femoris* passes obliquely from the anterior, superior spinous process of the ilium to the membrane which binds down the muscles of the thigh on the outside.

The *sartorius* is a long flat ribbon-like muscle, passing obliquely down from the front margin of the ilium to the side of the tibia just below the tuberosity.

The great extensor of the leg, the *quadriceps*, consists of four parts—(1) the *rectus femoris*, passing down from the anterior, inferior spinous process and the brim of the acetabulum; (2) the *vastus externus*, and (3) the *vastus internus*, fleshy masses attached respectively to the outer and inner sides of the shaft of the femur; and (4) the *crureus*, consisting of fibres springing from the front of the thigh-bone. The whole are inserted, by a tendon attached to the patella, into the tuberosity of the tibia.

Gracilis. A muscle thus named, flat and thin, springs from the pubis (close to its symphysis), and is inserted by a tendon into the tibia beside the tuberosity.

The *pectineus* passes from the ilio-pectineal line to the femur below the lesser trochanter.

The *adductores longus*, *brevis*, and *magnus*, pass downwards and outwards from the pubis to the femur, and are respectively inserted into the middle third of the linea aspera, into below the lesser trochanter, and into the whole length of the linea aspera down to the inner condyle.

Three muscles, called the ham-string muscles, are—(1) the *biceps femoris*, which springs both from the femur and (by tendon) from the tuberosity of the ischium, and is inserted into the head of the fibula; (2) the *semi-tendinosus*, which arises from the ischium in common with the last, and is inserted inside the tibia, below its tuberosity; (3) the *semi-membranosus*, which springs from the tuberosity of the ischium (in front of the origin of the *biceps*), and is inserted triply, (*a*) into the tibia behind its inner tuberosity, (*b*) under the internal lateral ligament at the side of the inner tuberosity, (*c*) into the external condyle of the femur.

13. The MUSCLES OF THE LEG consist in front of seven muscles.

The *tibialis anticus* extends along the outer side of the tibia downwards from its outer tuberosity, and ends below in a tendon which is inserted into the ento-cuneiforme and first metatarsal.

The *extensor proprius hallucis* arises from the fibula and the interosseous membrane connecting that bone with the tibia. Its tendon is inserted into the second phalanx of the great toe.

The *extensor longus digitorum pedis* arises from the fibula and interosseous membrane and outer tuberosity of the tibia. Below, it ends in four tendons going respectively to the second and third phalanges of the four outer (peroneal) digits.

The *peroneus tertius* is placed on the front of the fibula's lower third, and its tendon is inserted into the dorsum of the fifth metatarsal.

The *extensor brevis digitorum pedis* springs from the dorsal surface of the calcaneum and its annexed ligaments, and

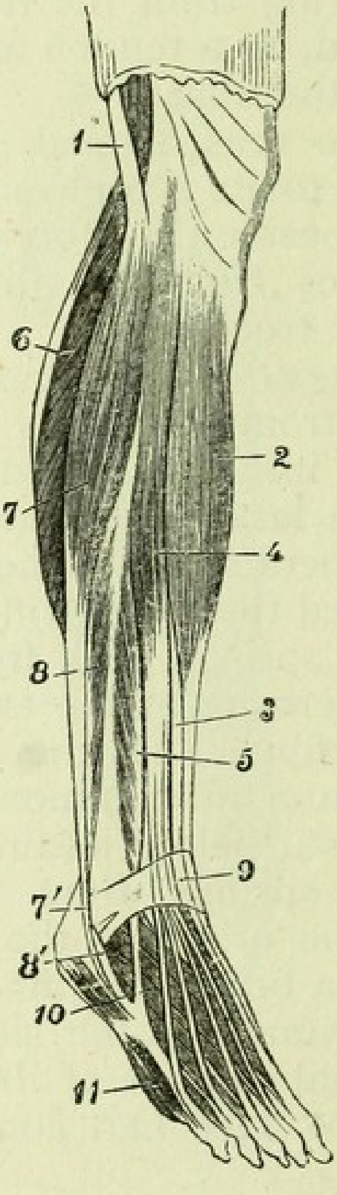

FIG. 279.—MUSCLES OF OUTER SIDE AND FRONT OF RIGHT LEG.

1, external lateral ligament; 2, tibialis anticus; 3, extensor hallucis; 4, extensor longus digitorum pedis; 5, peroneus tertius; 6, gastrocnemius; 7, peroneus longus; 7', its tendon; 8, peroneus brevis; 8', its tendon; 9, annular ligament; 10, extensor brevis pedis; 11, abductor minimi digiti pedis.

ends in four tendons, the most internal of which is inserted into the first phalanx of the hallux. The other three become respectively united to the long extensor tendons of the three next digits.

A remarkable muscle, the *peroneus longus*, arises from the outer, upper two-thirds of the fibula and from the external tuberosity of the tibia. It ends in a tendon which passes behind the external malleolus, and then obliquely across the sole of the foot to the first metatarsal.

The *peroneus brevis* springs from the outer, lower half of the fibula, and ends in a tendon which, also passing behind

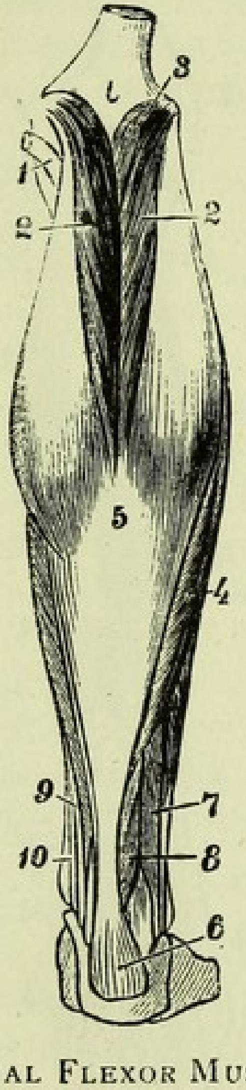

FIG. 280.—SUPERFICIAL FLEXOR MUSCLES OF RIGHT LEG.

1, tendon of semi-membranosus; 2, 2, heads of gastrocnemius; 3, plantaris; 4, soleus; 5, great tendon of gastrocnemius, continuous below with (6) the tendo Achillis; 7, peroneus longus; 8, peroneus brevis; 9, flexor longus digitorum pedis; 10, tibialis posticus.

the external malleolus, is inserted into the base of the fifth metatārsal.

Behind the leg we have seven muscles.

The *gastrocnemius* (forming the bulk of the calf of the leg) consists of two fleshy heads, arising each by a thick tendon from above each of the condyles of the femur—one external, one internal. They unite and send down the very strong *tendo Achillis* to be inserted into the tuberosity of the calcaneum.

The *soleus* lies beneath the gastrocnemius, and arises from behind the upper part of the fibula and tibia, while below it joins the tendo Achillis.

The *plantaris* springs from the femur above the external condyle, and gives rise to a very long tendon which goes to the calcaneum beside the tendo Achillis.

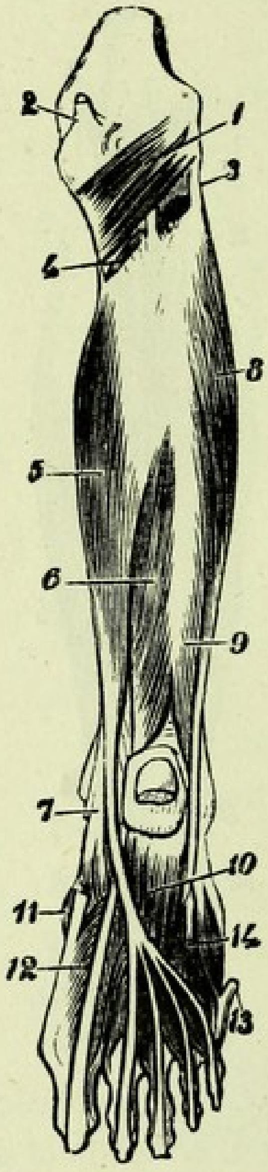

FIG. 281.—DEEP FLEXOR MUSCLES OF RIGHT LEG.

1, popliteus; 2, tendon of semi-membranosus; 3, external lateral ligament of the knee-joint; 4, cut upper extremity of soleus; 5, flexor longus digitorum pedis; 6, flexor longus hallucis; 7, tendon of tibialis posticus; 8, peroneus longus; 9, peroneus brevis; 10, accessorius; 11, abductor hallucis, cut short; 12, flexor brevis hallucis; 13, abductor digiti minimi, cut short; 14, flexor brevis minimi digiti.

The *popliteus* is a short oblique muscle which takes origin by a thick tendon from a pit outside the external condyle, and is inserted behind the tibia above the oblique line.

A muscle bends the toes, called the *flexor longus digitorum pedis*, arising behind the tibia below the popliteus. It ends in a tendon which passes behind the internal malleolus and beneath the calcaneal arch, and then divides into four tendons—one for each of the four outer digits at their distal phalanx, each perforating in its passage a tendon of the flexor brevis digitorum.

The long flexor is connected with a small muscle called *flexor accessorius*, which passes to the tendon of the flexor longus digitorum from the calcaneum.

The *flexor longus pollicis pedis* springs from the posterior surface of the fibula and the interosseous membrane. It ends in a tendon which passes behind the internal malleolus, grooving the tibia, astragalus, and calcaneum. In the sole it gives off a tendinous slip which joins the tendon of the flexor longus digitorum, and then ends by being inserted into the distal phalanx of the hallux.

The *tibialis posticus* arises from the hinder surface of the tibia (below the popliteus) and from the interosseous membrane. It ends in a tendon which first passes beneath the internal malleolus along a special groove, and then beneath the calcaneum, to be inserted into the tuberosity of the naviculare and the first metatarsal.

14. The MUSCLES OF THE FOOT, besides the flexor accessorius already noticed, consist of the following :—

The *abductor pollicis pedis*, which arises from the inner side of the calcaneum, and is inserted into the inner border of the first phalanx of the hallux.

The *flexor brevis digitorum* (or *perforatus*) arises from the great tuberosity of the calcaneum and from membrane, and ends in four tendons corresponding with the four smaller toes. Each tendon is inserted into the second phalanx of a digit, but splits opposite the proximal phalanx of the same digit in order to allow a tendon of the long or perforating flexor to pass through.

The *abductor digiti minimi* springs from the outer border and under surface of the calcaneum, and ends in a tendon inserted into the proximal phalanx of the fifth digit.

The *lumbricales*, like those of the hand, arise from the tendons of the perforating flexor, and are respectively inserted into the base of the first phalanges of the four outer toes.

The *flexor brevis pollicis pedis* springs from the cuboides and ecto-cuneiforme, and is inserted into the inner and outer borders of the first phalanx of the hallux.

The *abductor pollicis pedis* takes origin from the cuboides and third and fourth metatarsals. Passing obliquely, it is inserted conjointly with the external insertion of the *flexor brevis pollicis.*

The *transversus pedis* is a narrow band stretching from the distal ends of the metatarsals and blending with the insertion of the adductor pollicis into the first phalanx of the hallux.

The interosseous muscles are like those of the hand, except that it is the *second* digit, not the third, which has two dorsal interossei. This condition results simply from the fact that the origin (from the metatarsal) of the fibular interosseus of the second digit is placed on the dorsal side of the tibial interosseus of the middle digit.

Such is the normal condition of man's muscles, but these structures are liable to considerable individual variation.

15 On turning to other Vertebrate animals in order to estimate the peculiarity of man's muscular structure, we find that, as regards the MUSCLES OF THE HEAD AND NECK, the *occipito-frontalis* truly belongs to a distinct category of "skin-muscles," whereof the *platysma myoides* also forms a part. This dermal group of muscles is very feebly represented in man compared with what we find in brutes, *e.g.* the Horse, where it is termed the *panniculus carnosus*, and by its contractions produces those twitchings of the skin which must be familiar to most readers. It is most developed in such forms as the Porpoise (where it envelops the whole body from the occiput to the tail end), the Echidna, and the Hedgehog. In the last-named animal it is so complex that it may be divided into nine pairs of muscles, one pair being the "occipito-frontalis." When all these muscles contract, the animal becomes "rolled up," the limbs becoming, as it were, enclosed in a muscular bag. The panniculus is commonly inserted into the arm and leg, and part of it may, as in the Echidna, be applied round the mammary gland, which it serves to compress.

Muscles such as those which exist in man's face may be wanting altogether, as *e.g.* in the Tortoises, but some of them may, as we shall see, be much more developed in certain animals than they are in him.

Thus we may have his *superior auricular* represented by two muscles, and his *anterior auricular* and his *posterior auricular* by four, together with two or three extra muscles, as in the Horse.

Palpebral muscles may be wanting, as in Serpents, and the *orbicularis palpebrarum* may be atrophied, as in Whales, or replaced by a complete sphincter, as in *Tetraodon*.

The muscles of the *nasal region*, so important for expression, do not in most animals attain the distinctness they do in man. Yet they may be distinct where little expression is to be detected, *e.g.* in the Great Ant-eater. They may all abort, as in the Crocodile, or they may receive certain additions, as in the Pig, where two muscles arise, one on each side, from the zygoma and maxillary bone, and unite together above the end of the snout, which they elevate ; while two other muscles (which depress the snout) take origin, one on each side, from the zygoma, and are inserted into the median septum. In the Mole there are even four on each side, all arising above the ear and passing forwards between the temporal and masseter muscles, to be inserted into the extremity of the muzzle.

The most exceptional modification of the nasal and labial muscles is, however, found to exist in the Elephant, where they form its remarkable trunk. For this purpose two muscles (elevators) take origin, one on each side, from processes above the nasals. Another pair (depressors) spring from the pre-maxillæ, while a third pair (lateral, longitudinal muscles) take their origin from the frontal and maxillary bone on each side. Besides these there are intrinsic muscles of the proboscis, the fibres of which radiate from the nasal passages to the inner surface of the skin, and tend to keep the former open.

Another peculiar condition is that existing in Cetacea, which will be noticed in treating of the nose as a sense organ. Here, however, it may be mentioned that in the Porpoise a muscular layer spreads forwards from the frontal bone over the posterior nasal structures, and another layer spreads backwards from the maxillary bone over the anterior nasal structures. It is by the contraction of these muscles that the nasal passage is opened while the nasal sacs are compressed and their contents ejected.

The *masseter* may attain a relative size and complexity which are very much greater (especially when compared with the simultaneous condition of the temporal) than in man. This great development is well seen in certain Rodents, *e.g.* *Lagostomus* and the Agouti, where the masseter is divided into three portions, and traverses the singularly enlarged infra-orbital foramen spoken of in describing the skeleton.

This muscle, even in Mammals, may be blended with the temporal, as is the case in the Two-toed Ant-eater.

The *temporal* muscle of man is but very poorly developed compared with what we find in many other forms, such as the Tiger. It may, on the contrary, be less developed relatively than in man, as in the Hare. It may be divided into three or four portions, as in the Fowl and Goose.

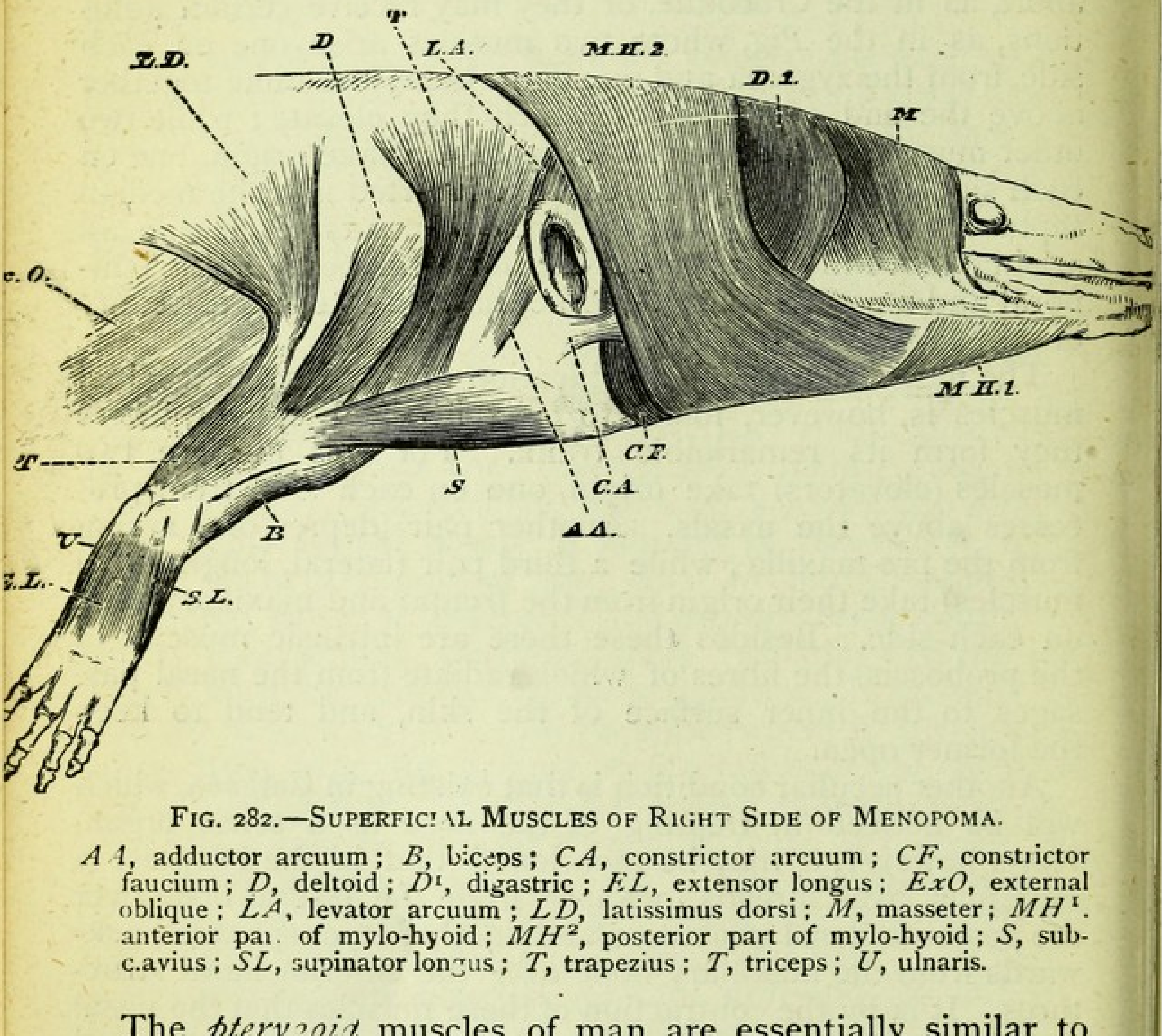

FIG. 282.—SUPERFICIAL MUSCLES OF RIGHT SIDE OF MENOPOMA.

AA, adductor arcuum; *B*, biceps; *CA*, constrictor arcuum; *CF*, constrictor faucium; *D*, deltoid; *D*[1], digastric; *EL*, extensor longus; *ExO*, external oblique; *LA*, levator arcuum; *LD*, latissimus dorsi; *M*, masseter; *MH*[1], anterior part of mylo-hyoid; *MH*[2], posterior part of mylo-hyoid; *S*, subclavius; *SL*, supinator longus; *T*, trapezius; *T*, triceps; *U*, ulnaris.

The *pterygoid* muscles of man are essentially similar to the same parts in the whole of his class; but these muscles may be indistinguishably united into one, as in *Menopoma*, or even with the temporal, as in *Menobranchus* (Fig. 286). They may be very large, as in venomous Serpents.

16. The ORBITAL MUSCLES of man present a condition which is normal, these parts exhibiting a remarkable constancy in vertebrate animals.

Such parts, however, may be entirely wanting even in

Mammals, e.g. *Talpa* and *Spalax;* and in *Lepidosiren*, the Lamprey, and Lancelet amongst Fishes.

On the contrary, muscles may be developed which do not exist in man at all.

Thus in most Mammals (*e.g.* the Horse) a conical funnel-shaped muscular mass may spring from around the optic foramen, and, passing within the recti, attach itself to the sclerotic.

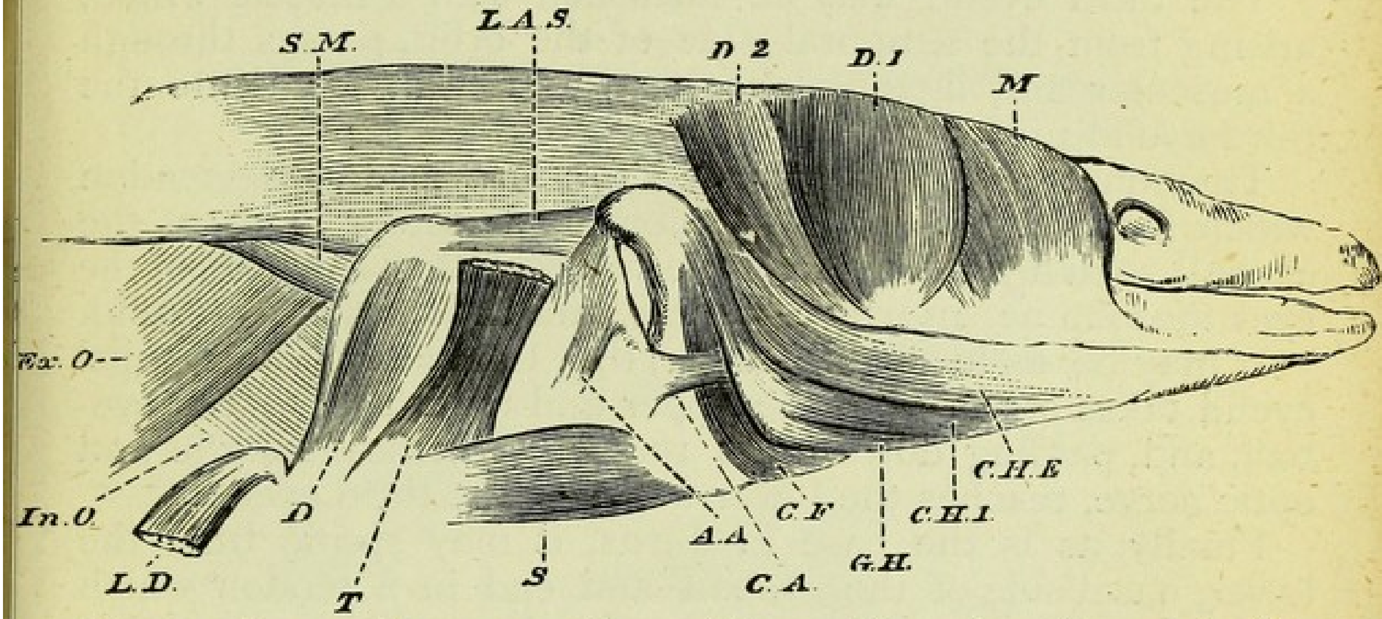

FIG. 283.—DEEPER MUSCLES OF RIGHT SIDE OF MENOPOMA (the mylo-hyoids and trapezius being removed or cut short).

AA, adductor arcuum ; *CA*, constrictor arcuum ; *CF*, constrictor faucium ; *CHE*, cerato-hyoideus externus ; *CHI*, cerato-hyoideus interus ; *D*, deltoid ; D^1 and D^2, digastric ; *ExO*, external oblique ; *GH*, genio-hyoideus ; *InO*, internal oblique ; *LAS*, levator anguli scapulæ ; *LD*, latissimus dorsi ; *M*, masseter ; *S*, subclavius ; *SM*, serratus magnus ; *T*, trapezius.

This mass may divide itself into two portions, as in the Rhinoceros ; three, as in the Frog ; or into four, as in the Porpoise. In the last case we have thus four supplementary recti muscles within the four normal ones.

It may be that the superior oblique muscle does not pass through a pulley. It does not do so in Vertebrates below Mammals, where it arises at the front part, not the back of the orbit.

The two oblique muscles may thus arise, one above the other, from the inner angle of the orbit, as in the Frog and in Fishes.

The muscles of the eye may take origin in part from the basis cranii and in part from the fronto-parietal, as in the Frog ; or they may spring from within a bony canal situated beneath the basis cranii, as in many bony Fishes, *e.g.* the Carp.

The eye muscles may attain a prodigious length, as in the Hammer-headed Shark, where they arise from the basis cranii and extend the whole length of the prolonged lateral processes which support the eyeballs at their ends.

There may be a distinct depressor of the lower eyelid, and in addition to this, other muscles may be developed in connexion with the third eyelid, which is of large size in so many animals, notably in Birds.

The third eyelid may be furnished with a muscle which, arising from the temporal side of the orbit, passes through a muscular and ligamentous loop, and is inserted into the third eyelid's inferior margin.

This muscle may be, as in the Frog, furnished with a tendon which forms a loop over the conical muscular mass of the eyeball, so that when that muscle swells by the retraction of the eyes the loop necessarily contracts, and thus moves the eyelid.

It may be, as in the Crocodile, that the muscle of the third eyelid takes origin from the upper and inner part of the eyeball, and, passing downwards round the conical muscle and optic nerve, reaches the lower angle of the third eyelid.

Finally, as is the case in Birds, it may spring from the lower, nasal side of the eyeball and end in a tendon which proceeds to its insertion as in the Crocodile, except that it passes through a pulley formed by the tendinous sheath of a second muscle (the *quadratus nictitantis*) which arises from the sclerotic at its upper and back part, and ends in forming the sheath aforesaid. As in Birds there is no conical muscle, this quadrate one is probably its representative.

Another muscle may also exist, as in the Frog, forming a sort of fleshy sheet on which the eyeball rests, and which protrudes the eyeball by its contraction.

17. As to the MUSCLES OF THE NECK.

The *sterno-cleido-mastoid* of man really represents what are two muscles in many other animals, viz. a sterno-mastoid and a cleido-mastoid. Nevertheless it may be a single muscle even in Reptiles, as in the Iguana.

The sterno-mastoid may be wanting altogether, as in Birds and Batrachians.

The cleido-mastoid may also be wanting, and it may, as in the Horse (by suppression of the clavicle and uninterrupted union with the deltoid or pectoralis), extend directly from the skull to the humerus as a cephalo-humeral, or even to the ulna, as in Hyrax.

In cold-blooded Vertebrates this muscle may be attached to the fronto-parietal or to the suspensorium, and it may, even in Mammals, be inserted above into the mandible, as in the Horse.

The *digastric* of man is closely resembled only by the same muscle in his own order. In other Mammals, *e.g.* the Dog, it has but a single belly; and in lower Vertebrates the muscle which commonly receives this name has a very different position. Thus in Birds and Reptiles it descends from the

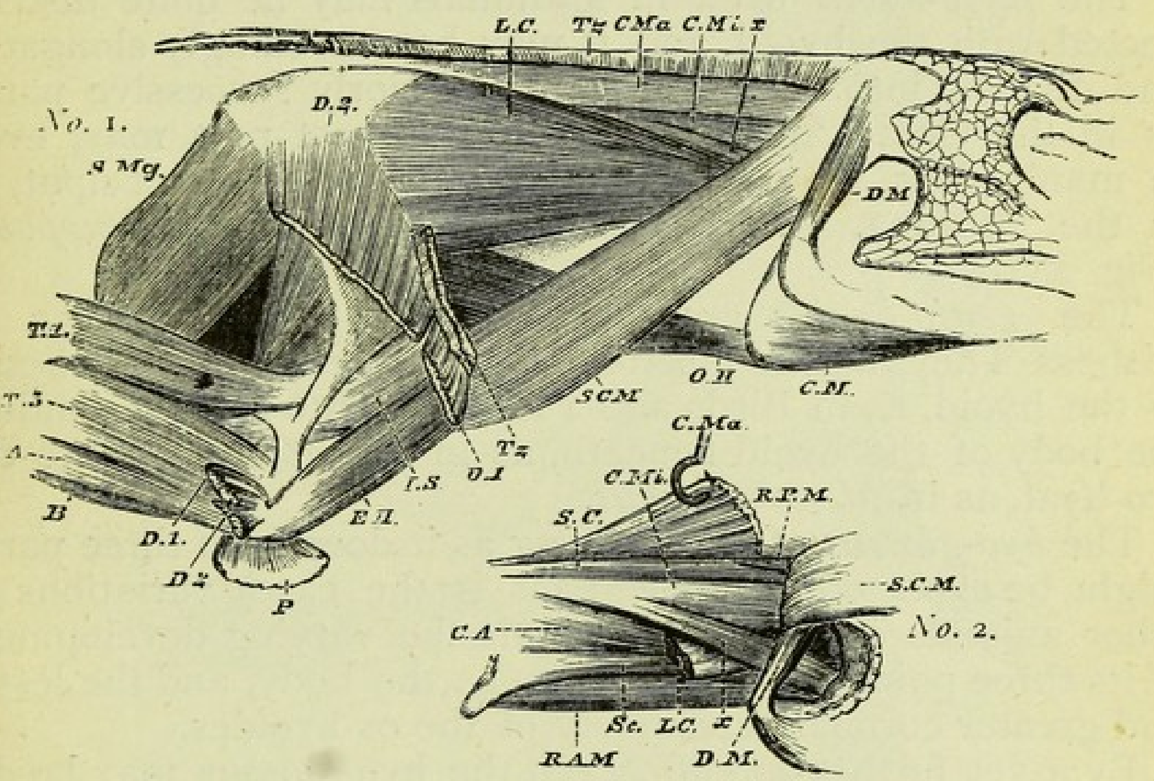

FIG. 284.

No. 1.—MUSCLES OF NECK AND SHOULDER OF *Iguana*, the trapezius and deltoid being cut short.

B, biceps; *BA*, brachialis anticus; *CM*, cerato-mandibular; *CMa*, complexus major; *CMi*, complexus minor; D^1 and D^2, two parts of deltoid; *DM*, digastric; *EH*, epicoraco-humeral, or sub-clavius; *IS*, infra-spinatus; *LC*, levator claviculæ; *OH*, omo-hyoid; *P*, pectoralis; *SCM*, sterno-cleido-mastoid; *SMg*, serratus magnus; T^1, external long head of triceps; T^3, external humeral head of triceps; *Tz*, trapezius; *x*, part of complexus.

No. 2.—DEEPER MUSCLES.

CA, cervicalis ascendens; *CMa*, complexus major; *CMi*, complexus minor; *DM*, depressor mandibulæ; *RAM*, rectus capitis anticus major; *RPM*, rectus capitis posticus major; *Sc*, scalenus; *SCM*, sterno-cleido-mastoid; *x*, part of complexus.

hinder part of the cranium to the posterior end of the mandible, and in some Birds is divided into three portions.

The *stylo-hyoid* of man is a muscle constant in his class, but of variable size. It may be of extraordinary length, as in the Great Ant-eater, and it may be, as in the Horse, relatively shorter than in man, the bony extent of the anterior cornua being so much greater than in the human structure. It may be attached above to the par-occipital process, as in the Horse, or to the posterior part of the lower jaw, as in some Birds, *e.g.* the Fieldfare.

The *stylo-glossus* and *stylo-pharyngeus* present few differences in Mammals, except that the former may take origin from the paramastoid process (as in Hyrax), or low down on the anterior cornu, as in Ruminants.

The *mylo-hyoid* even in Mammals may be quite disconnected with the hyoid, and it may be exceedingly elongated and divided into several antero-posteriorly successive parts, as in the Great Ant-eater. The hindmost part may, even in man's class, take origin from the sides of the occiput, as in the Echidna. It may be very large, as in *Menopoma* (Fig. 282).

The *genio-hyoids* are very constant, existing down to Fishes. They may be inserted into the cornua (not the body) of the hyoid, as in Birds and Fishes, or into fascia bounding the body of the hyoid beneath, as in *Menopoma*, or into the uro-hyal, as in *Menobranchus*.

The *hyo-glossus* of man, arising as it does from three parts, might be expected to present (as is the case) variations in other animals in accordance with the varying development of its three points of origin, namely, the body, and the lesser and greater cornua respectively of the os-hyoides.

By a yet further modification the hyo-glossus may be detached from the hyoid and blended with a sterno-hyoid also detached from the hyoid, so that we have an enormously long muscle entering into the substance of the tongue, but taking origin as far back as the xiphoid cartilage. Such is the case in the Great Ant-eater, where the hyo-glossi are reinforced by small muscles springing from the anterior cornua. Both lateral and median muscles exist in most Birds, and lateral muscles (*i.e.* from the cornua to the tongue) exist in Reptiles and the Frog, and even in some Fishes, all but tongueless as are the last-named animals.

The *genio-glossus* may take origin from the sides of the mandibular rami instead of from the symphysis, as in Serpents, or it may have two origins (one from the symphysis and one from the side of the mandible), as in the Great Ant-eater. This muscle may be wanting altogether, as in Fishes, and even amongst Birds—while nevertheless it exists not only in Reptiles but also in Batrachians (*e.g.* the Frog, *Salamandra*, and *Menobranchus*).

Other muscles, not present in man, may exist where complex branchial arches replace his rudimentary thyro-hyals or

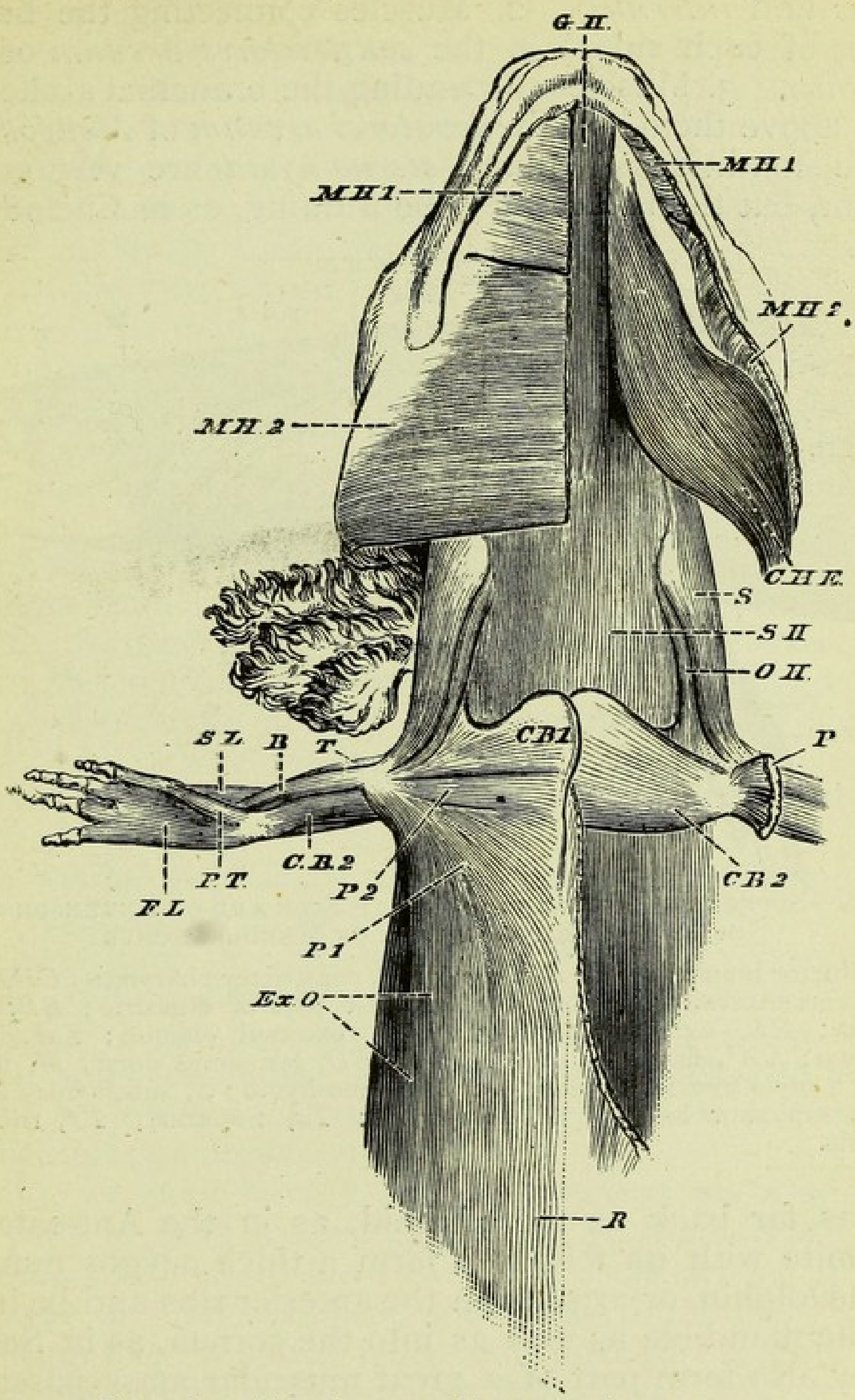

FIG. 285.—MUSCLES OF VENTRAL SURFACE.

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.

cornua. Thus we may have—1. Muscles connecting the hyoidean and branchial arches (*e.g.* the *cerato-hyoideus externus* and *internus*). 2. Muscles connecting the branchial arches of each side (*e.g.* the *constrictores arcuum* of *Menobranchus.* 3. Muscles suspending the branchial arches to the parts above them—as the *levatores arcuum* of *Menobranchus.*

The conditions of man's *sterno-hyoid* are very generally present, but the muscle may be wanting, as in Chelonians, or

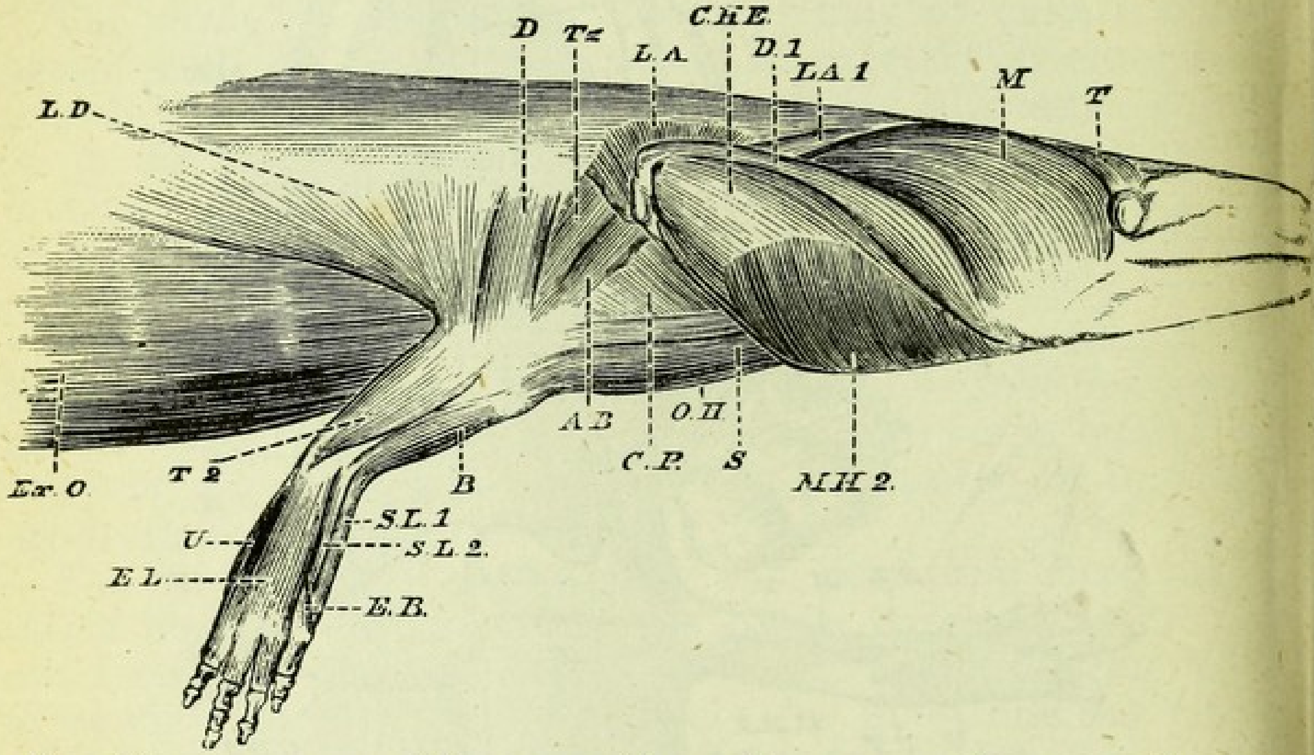

FIG. 286.—SUPERFICIAL MUSCLES OF RIGHT SIDE AND OF EXTENSOR SURFACE OF RIGHT PECTORAL LIMB OF MENOBRANCHUS.

AB, adductor branchiarum ; *B*, biceps ; *CP*, constrictor pharyngis ; *CHE*, cerato-hyoideus externus ; *D*, deltoid ; *D*1, first part of digastric ; *EB*, extensor brevis ; *EL*, extensor longus ; *ExO*, external oblique ; *LA*, levatores arcuum ; LA^1, first part of the same ; *LD*, latissimus dorsi ; *M*, masseter ; MH^2, mylo-hyoideus posterior ; *OH*, omo-hyoid ; *S*, subclavius ; SL^1 and SL^2, supinator longus ; *T*, temporalis ; *Tz*, trapezius ; T^2, triceps ; *U*, ulnaris.

arise as far back as the xiphoid, as in the Ant-eaters. It may unite with its fellow to form a thick azygos muscle, as in the Dolphin, or arise from the anterior ribs and be inserted into the mandible as well as into the cornua, as in Serpents. It may also form part of a great muscular mass passing uninterruptedly from the pelvis to the hyoid, as in *Menobranchus*, and thus we see that it enters into the composition of that part of each great lateral muscle which in Fishes is inserted into the median portion of the hyoidean arch.

A separate *sterno-thyroid* and a distinct *thyro-hyoid* are structures peculiar to man's class. The former blends with the sterno-hyoid even in the Platypus. It may, as in the Great Ant-eater, take origin as far back as the eighth bone of the sternum.

The *omo-hyoid* may be wanting even in Mammals, as *e.g.* in the Dog. We find it, however, in Reptiles and Batrachians, though absent in Birds. It may arise from the clavicle (as *Iguana*), from the pre-coracoid (as *Menobranchus*), or be bent at almost a right angle, looping round the sterno-mastoid (as in the Chameleon).

18. In the VERTEBRAL REGION there may be three *scaleni* muscles, as in man, or but one. They may vary also as to the number of ribs from which they take origin, and may reach even to the basi-occipital (as in the Agouti), or to the mastoid process (as in the Dolphin). They may be plainly but a continuation forwards of the *levatores costarum*, as in Birds.

They may be feebly developed, as in Reptiles, extending as in Iguana from the first four cervical vertebræ, or from the atlas, to the first cervical rib, as in *Iguana* and *Chameleo.* Finally, the scaleni may be indistinguishably blended with the dorsal muscular mass, as in Batrachians and Fishes.

The *rectus capitis anticus major* may attain a much greater development than in man, extending down to the sixth dorsal vertebra.

The *longus colli* may arise as far back as the seventh dorsal vertebra, as in the Agouti.

We may have in Chelonians (e.g. *Emys*) a very elongated muscle extending from even the hindmost thoracic vertebræ and going to the basi-occipital, and beneath this a series of little muscles (extending each from one vertebra to the next but one in front) connecting together the cervical vertebræ and the anterior dorsal ones.

Again, we may have a simple muscular mass answering apparently to both *longus collus* and *rectus anticus.* Thus in the Chameleon we have such a muscle arising from the first eight or nine vertebræ, and going to the basi-occipital. The origin may be much more extensive in Serpents (where the hypapophyses afford points of origin), and in certain Batrachians (e.g. *Menopoma* and *Menobranchus*) a corresponding muscle stretches on each side from beneath the basis cranii throughout the whole trunk, and, diminishing backwards, ends (or rather arises) in the sub-vertebral part of the pelvic region.

The *rectus lateralis* is really but the highest of the *inter-*

transversales. It is a constant muscle in man's class, varying in size with the dimension of the atlantic transverse process, and therefore being large in the Carnivora.

The *pharyngeal* muscles of man are structures which are exceptional amongst Vertebrates, as they are developed in the highest class alone.

In Birds, Reptiles, Batrachians, and Fishes there are no proper constrictors of the pharynx, but only fibres which are quite homologous with those of the œsophagus.

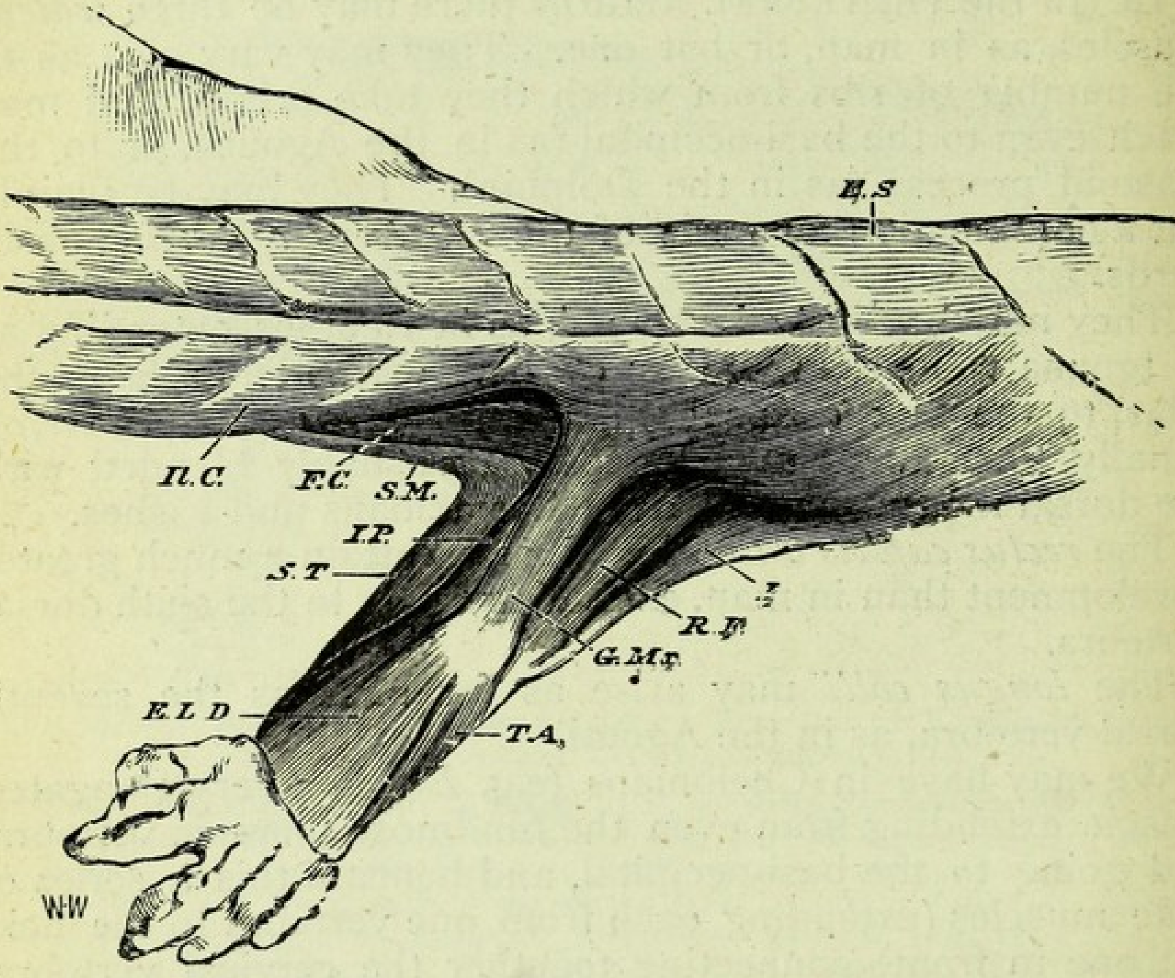

Fig. 287.—Superficial Muscles of Extensor Side of Leg and of farts of Trunk and Tail of Menopoma.

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-tendinosus.

These fibres may, however, form a well-developed pharyngeal sphincter, as in Fishes, and serve for moving those "throat-jaws," the pharyngeal bones, which exist in so many of the lowest Vertebrate class.

Much variety in form and in the details of attachment may, however, exist in the Mammalian pharyngeal constrictors, and we may find a greater degree of complexity than in man.

The muscles belonging to man's *palatal* region are special Mammalian muscles, and present in the class generally the same disposition as in him. The pendulous palate becomes in the Cetacea a muscular canal prolonging the posterior nares to the elongated larynx which it embraces.

19. The MUSCLES OF THE BACK of man present characters as exceptional, when compared with those of Vertebrates generally, as does his axial skeleton. The non-development of a tail and the large size of the upper extremities are occasions in him of muscular conditions which differ greatly from those presented by many other forms.

Thus the first and second layers may be entirely wanting, and the other muscles may be represented (as in *Menopoma* and *Menobranchus*) by one great mass, running from the head to the end of the tail on each side of the vertebral neurapophyses; and this again may be, as in Fishes (*e.g.* the Perch), divided by a number of aponeuroses more or less at right

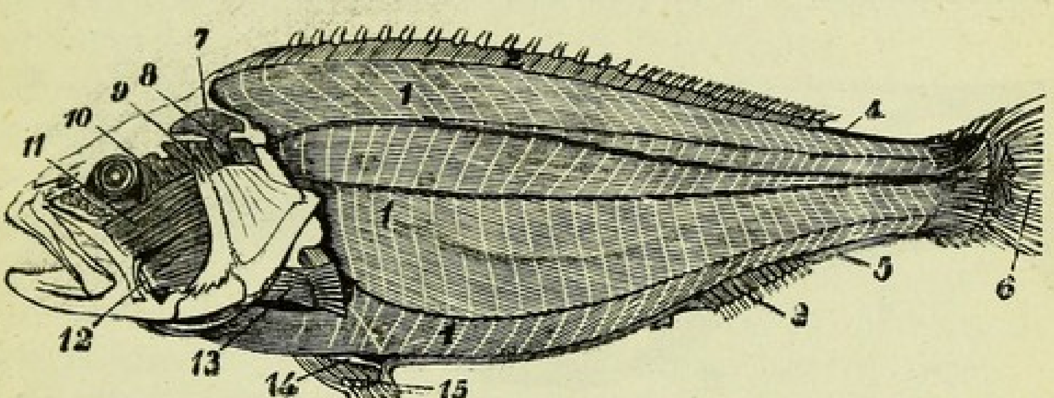

FIG. 288.—SUPERFICIAL MUSCLES OF THE PERCH. The fin-rays of all the fins are cut short off.

1, great lateral muscle, showing the numerous more or less vertical tendinous intersections slightly inflected forwards and backwards; 2, small superficial muscles inserted into the fin-rays of the dorsal and ventral fins; 4, 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 which by its contraction closes the jaws; 13, superficial muscles of the pectoral fin; 14 and 15, muscles of the ventral fin.

angles to the backbone, so that the dorsal muscular mass comes to consist not of segments extended in the line of the skeletal axis, but of segments extending almost at right angles to that axis.

The muscles of the back may be much less developed, relatively, than in man, as is the case in Birds; or they may be all but absent, as in Chelonians. They may, on the contrary, be excessive in mass, as in most Fishes, or in complexity, as in Serpents.

The *trapezius* is a very constant muscle, but may be much more restricted or more extended in its origin than is the case in man. It may also be divided into two portions, as notably in the Mole, where the two origins are very wide apart: (1) the occiput, and (2) the first two lumbar vertebræ. It may be very small, as in *Menobranchus* (Fig. 286) or may unite with the latissimus dorsi, as in *Anguis fragilis*, or with part of the deltoid, so as to go directly to the humerus as in some Mammals without clavicles.

In Bats a long slender segment of this muscle may pass along the upper margin of the wing membrane from the occiput to the distal phalanx of the pollex.

In the Flying Squirrel *Pteromys* a similar muscular band goes to the rudimentary pollex, but it springs from the zygoma, and is therefore rather a modification of the platysma myoides than of the trapezius; as it is also in *Galeopithecus*

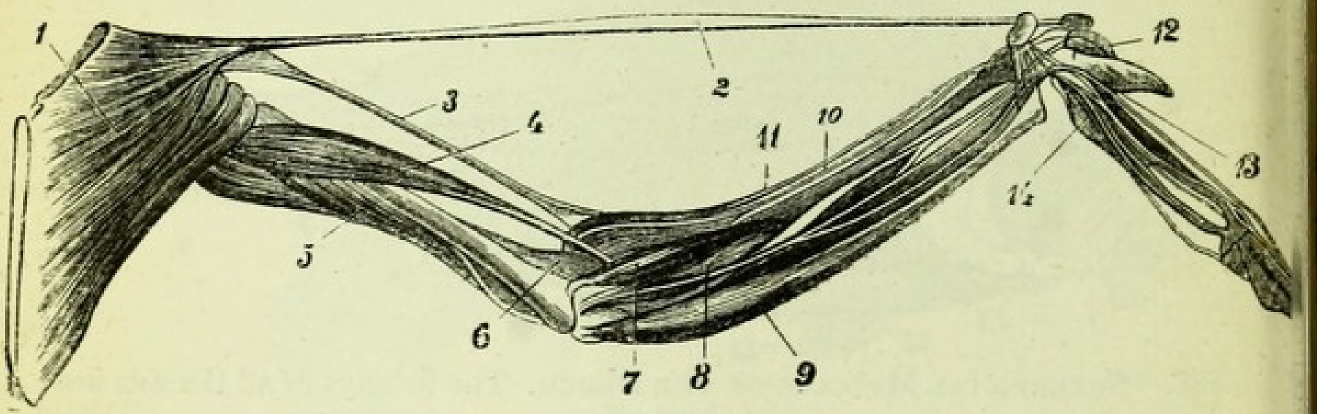

FIG. 289.—MUSCLES OF THE VENTRAL ASPECT OF THE BREAST AND LEFT WING OF AN EAGLE (*Aquila fucosa*).

(*After A. Milne-Edwards.*)

1, pectoralis major, sending out a slip, 2 (as the tensor petagii longus) to the first metacarpal; 3, tensor petagii brevis; 4, biceps; 5, triceps; 6, brachialis anticus; 7, pronator brevis; 8, pronator longus; 9, flexor carpi ulnaris; 10 extensor metacarpi radialis longus; 11, extensor carpi radialis; 12, abductor pollicis; 13, points just above a long tendon of the flexor profundus; 14, flexor brevis digitorum.

In Birds an analogous and similarly slender muscle goes to the pollex or to a sesamoid at its base, but this muscle is often an offshoot from the pectoralis major, though it may contain fibres from the deltoid or from the biceps—showing in what diverse ways a similar want may be supplied.

The *ligamentum nuchæ* of man is but a rudiment of that vast band, or sheet, of fibres which in many animals (*e.g.* the

Horse) extends from the spines of the dorsal vertebræ to the occiput, sending down a lamellar expansion to the spines of the cervical vertebræ. In the Giraffe it extends back even to the sacrum.

This ligament may become ossified, as in the Mole.

The *latissimus dorsi* is another nearly constant muscle, though of varying extent. It may, as in many Apes, send a slip on to the olecranon, or even, as in the Echidna, to the *flexor carpi ulnaris* with which it blends. It may be divided into two parts, as is the case in the Echidna. It may arise within the ribs, as in Chelonians, e.g. *Emys*. It may be very small, as in *Menopoma* (Fig. 282). Finally, it may completely unite with the trapezius, as in *Anguis fragilis*, or it may be altogether wanting.

The *rhomboidei* may be more divided than in man, as in the Mole; or single, as in the Hawk; or absent, as in the Apteryx and apparently in lower forms. A *rhomboideus capitis*, which sometimes exists in man, is often present in lower forms, as *e.g.* in *Lemur* and *Nycticebus*.

Levator anguli scapulæ. This is essentially and morphologically the anterior part of that great muscle by which, in quadrupeds, the trunk is slung between the summits of the scapulæ—the greater part of which goes by the name of the *serratus magnus*—rather than a really distinct muscle.

There is a muscle commonly existing in Mammals, but which is developed only by rare exception in man. This (the *levator claviculæ*) extends from the atlas to the scapula or to the clavicle ; it is well seen in Apes. It is a muscle of considerable constancy, as it is found of a very large relative size in Reptiles, e.g. *Iguana* (Fig. 284). It may arise from the occipital region, as in *Chameleo*.

Another muscle, not found in man, but developed in some Mammals (*e.g.* the Horse and Hyrax), is termed the *sterno-scapular*. It extends from the sternum over the scapulo-humeral articulation to the superior vertebral angle of the scapula.

The *serrati postici superior* and *inferior* are both represented in many Mammals by one single continuous muscle, which seems to attain its maximum of development in the Hyrax. Only the inferior *serratus posticus* may be present, as in the Three-toed Sloth, while sometimes (as in the Bats) it is the superior which is exclusively, or all but exclusively, developed.

The *splenius capitis* is a muscle the possession of which man shares with his class, but which may have no distinct representative in non-mammalian forms which are higher than Batrachians, *e.g.* in the Iguana.

The *splenius colli* is present only in a few Mammals.

The *erector spinæ* presents in man a degree of differentiation not generally found in animals below his class. Thus in the Iguana and Chameleon it is but divisible into the longitudinal parts answering respectively to the *longissimus dorsi*

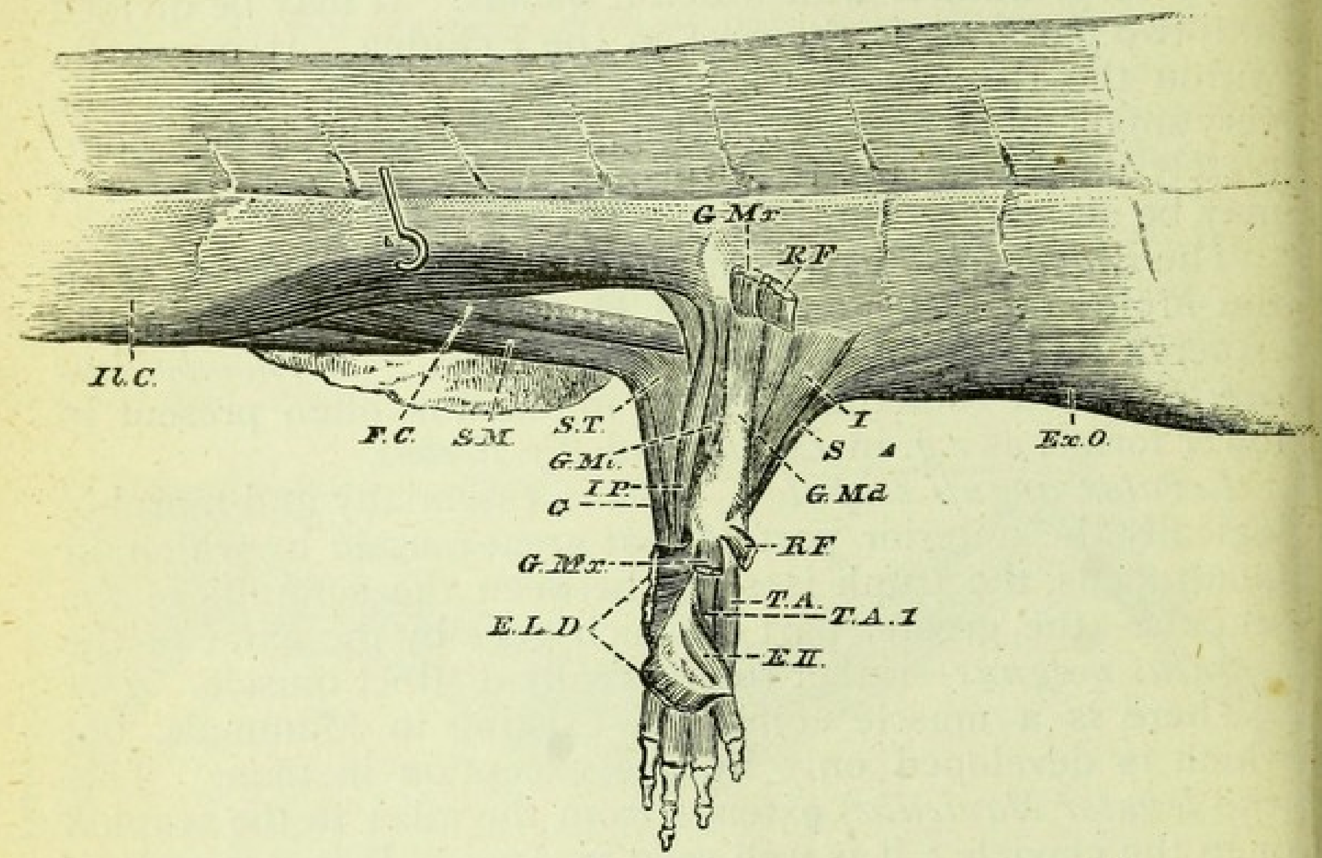

FIG. 290.—DEEPER MUSCLES OF OUTER SIDE OF HINDER PART OF TRUNK AND ANTERIOR PART OF TAIL, AND OF THE DORSAL (EXTENSOR) SIDE OF RIGHT PELVIC LIMB OF *Menobranchus*—the gluteus maximus, rectus femoris, and extensor longus digitorum being cut and reflected.

EH, extensor hallucis; *ELD*, extensor longus digitorum; *ExO*, external oblique; *FC*, femoro-caudal; *G*, gracilis; *GMd*, gluteus medius; *GMi*, gluteus minimus; *GMx* and *RF*, great extensors of thigh; *I*, iliacus (?); *IlC*, ilio-caudal; *IP*, ilio-peroneal; *S*, sartorius; *SM*, semi-membranosus; *ST*, semi-tendinosus; *TA* and *TA* [1], tibialis anticus.

and *sacro lumbalis*, and continuing, with the intervention of certain neck muscles, from the cranium to the end of the dorsum of the tail. But a greater simplicity still may exist, as in Tailed-Batrachians (e.g. *Menopoma* and *Menobranchus*), where, without the intervention of any such neck muscles, a simple, or more or less tendinously intersected muscular mass extends from the skull directly to the end of the dorsum of the tail. This dorsal muscle may be reduced to a mere rudiment, as in *Emys*, where it runs between the transverse and neural processes and the carapace.

The *cervicalis ascendens*. This anterior continuation of the sacro-lumbalis is of great constancy, appearing even in Reptiles, e.g. *Iguana* and *Chameleo*.

Transversalis cervicis. This muscle, which is the anterior prolongation of the longissimus dorsi, is less constant, as in at least some Reptiles, e.g. *Iguana* and *Chameleo* (Fig. 284), it does not seem to have any distinct existence.

The *complexus* is a muscle of great constancy, as it is found in Reptiles, e.g. *Iguana* and *Chameleo* (Fig. 284), while even in Batrachians and Fishes it must be considered as included in that part of the dorsal extensor mass which adjoins the head.

The *rectus capitis posticus major* is relatively much smaller in man than in many Mammals, compared with the *rectus capitis posticus minor;* while man's *obliqui capitis* are also relatively smaller than in very many. Thus in the Horse the posterior oblique has ten times the bulk of the more normally developed *rectus posticus minor*.

A whole series of muscles may be developed which in man are entirely absent. These are the numerous muscles which move the tail, and which may obtain a vast bulk, as in the Cetacea and in Fishes.

To describe these muscles in detail would rather come within the scope of a treatise on the Comparative Anatomy of

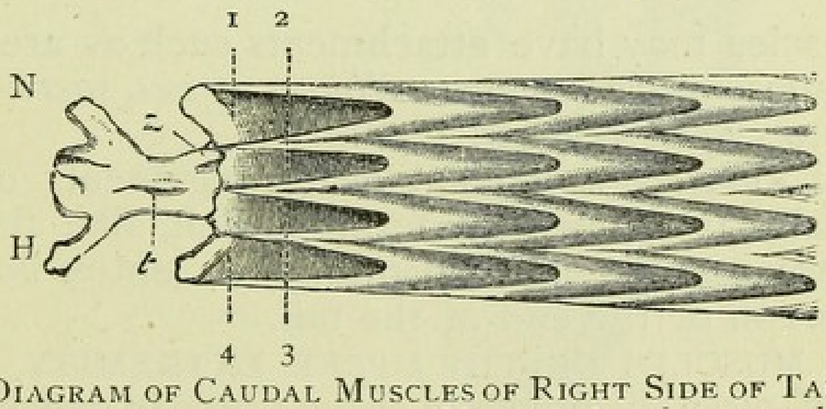

FIG. 291.—DIAGRAM OF CAUDAL MUSCLES OF RIGHT SIDE OF TAIL OF *Iguana*, showing how the ventral mass resembles the dorsal part, and how the tendinous intersections of the muscular fibres are drawn out into cones.

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 ; 4, ventral series of cones.

animals than within that of the present work. Here, however, it may be stated that the enormous coccyx of the Porpoise is provided not only with dorsal muscles which continue on backwards the erector spinæ (with its main divisions) from the occiput to the tail end, but also possesses a ventral muscular mass (extending forwards as far as the middle of the thorax), which mass is divisible from above downwards into two antero-posteriorly extended masses—together constituting, as it were, a ventral (and here sub-vertebral) reflection of the erector spinæ. The same appearance occurs in some Reptiles and in Tailed-Batrachians, where the ventral muscles of the tail repeat below, the dorsal masses above. But these Batrachian caudal muscles are not sub-vertebral—not the continuation backwards of sub-vertebral ones of the trunk, but direct continuations backwards of the abdominal muscles, as is also the case in most Fishes. Muscles of the tail (even in man's own order) may be very extensive, and

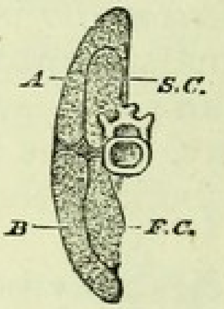

FIG. 292.—MUSCLES OF RIGHT HALF OF A TRANSVERSE SECTION OF THE TAIL OF *Iguana*, showing the separation of the caudal muscular cones from the vertebræ by the intrusion above of a supra-caudal mass from the trunk, and by the intrusion below of the femoro-caudal.

A, dorsal half of caudal cones; *B*, ventral half of caudal cones; *SC*, supra-caudal; *FC*, femoro-caudal.

caudal muscles may have attachments such as are indicated by their names—*pubococcygeus*, *ilio-coccygeus*, *sacro-coccygeus*, and *ischio-coccygeus* respectively.

Powerful muscles and complex arrangements of tendons are especially developed in forms which, like the Spider-Monkey, are capable of suspending the entire body by the grasping action of the end of the tail.

20. The MUSCLES OF THE UPPER EXTREMITY, as might be expected, often disappear in those forms in which an upper extremity is wanting. Just, however, as we found in the skeleton that we might have bones of the shoulder girdle without any of those of the arm, so we may have certain of the muscles in question attached to that shoulder girdle though the actual extremity be wanting. Such is the case in some Reptiles, *e.g.* in *Anguis fragilis*. The muscles may be greatly reduced in size where there is little variety of motion, as in Birds and Cetaceans. No profitable compari-

son can be instituted between the limb-muscles of man and of Fishes. Very simple muscular fasciculi represent in Fishes the complex structures of higher vertebrates.

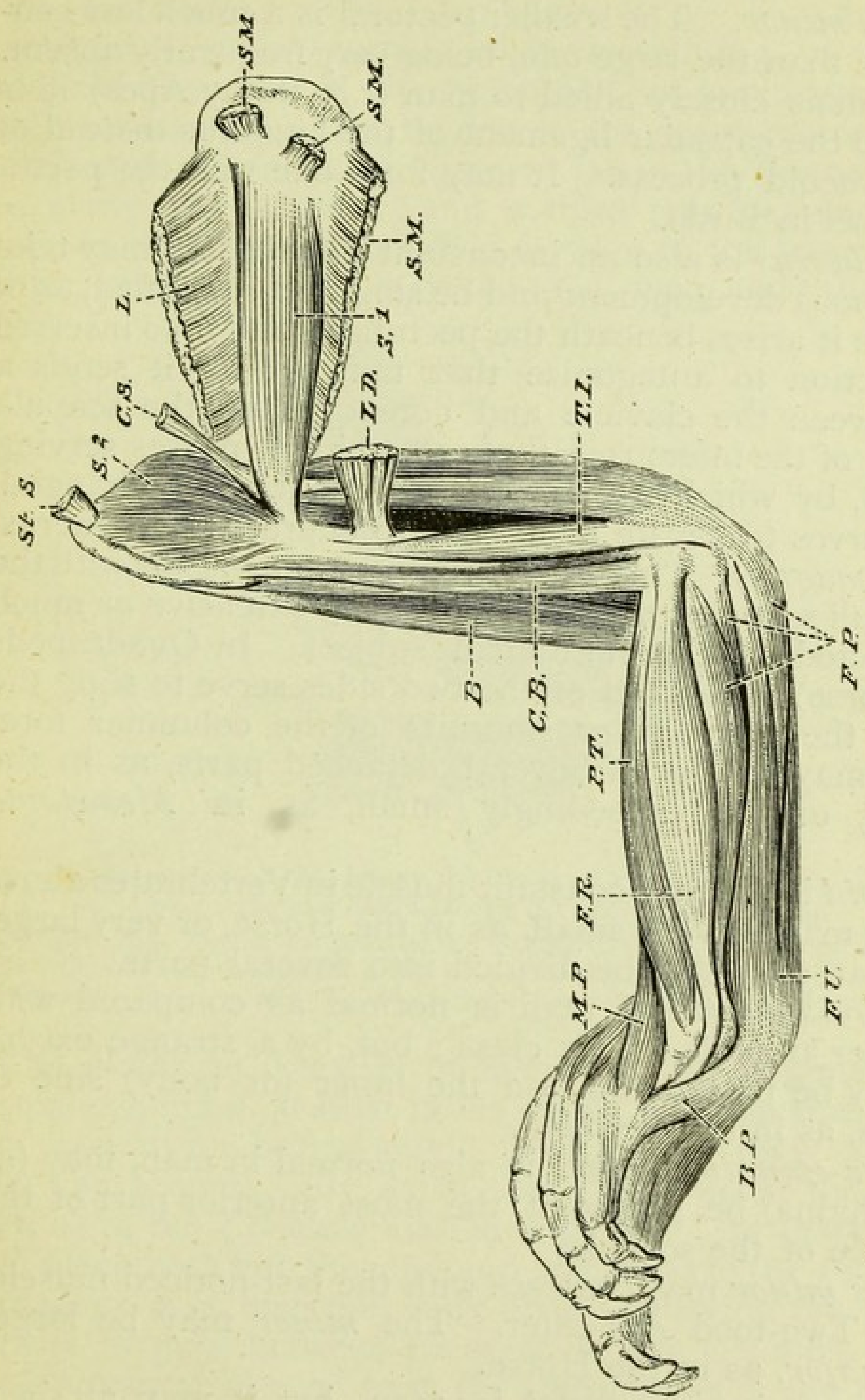

FIG. 293.—INNER SIDE OF RIGHT PECTORAL LIMB OF PARSON'S CHAMELEON.

B, biceps; *BP*, flexor brevis pollicis; *CB*, coraco-brachialis; *CS*, costo-coracoid ligament; *FP*, flexor longus pollicis; *FR*, flexor radialis; *FU*, flexor ulnaris; *L*, levator claviculæ; *LD*, latissimus dorsi; *MP*, extensor ossis metacarpi pollicis; *PT*, pronator teres; S^1 S^2, subscapularis; *SM*, serratus magnus; *StS*, sterno-coracoid; *TI*, internal part of triceps.

The *pectoralis major* is a nearly constant muscle, but one which may vary greatly as to its relative size to other muscles its degree of subdivision, and the details of its origin. Thus in many Birds it is the absolutely largest muscle, and equals the weight of all the other muscles of the body put together. In the last-named class it may send a slip to the pollex, as in the Eagle (see Fig. 289, 2).

Pectoralis minor. The smaller pectoral is a much less constant muscle than the large one, being very frequently absent. Even in animals closely allied to man (*e.g.* many Apes) it is inserted into the capsular ligament of the humerus instead of into the coracoid process. It may form one with the pectoralis major, as in Birds.

The *sub-clavius* is also an inconstant muscle. It may take on an enormous development and be singularly modified, as in Birds, where it arises beneath the pectoralis, and is so inserted as by its action to antagonize that muscle ; for it sends a tendon between the clavicle and coracoid, and the scapula (the margin of the interspace through which it passes serving as a pulley), by which the direction of its force is changed, so that it serves to elevate instead of to depress the humerus.

Serratus magnus. This, which really is one muscle with the levator anguli scapulæ, may be much more extensive or much more restricted than in the human subject. In Quadrupeds (*e.g.* the Horse) the serrati of the two sides serve to sling the trunk from the scapulæ, or summits of the columnar fore-limbs. It may consist of several detached parts, as in the Chameleon, or be exceedingly small, as in *Menopoma* (Fig. 283).

The *deltoid* is a nearly constant muscle in Vertebrates above Fishes, but may be very small, as in the Horse, or very large, as in the Bat, or it may be divided into several parts.

The *supra-spinatus* of man is normal as compared with that of other animals of his class ; but, by a strange exception, it may be placed only on the inner (or body) side of the scapula, as in the Echidna.

The *infra-spinatus*, which is also normal in man, may (as in the Echidna) be placed at the most anterior part of the outer surface of the scapula.

The *teres minor* may coalesce with the last-noticed muscle, as in the Two-toed Ant-eater. The *minor* may be larger than the *major*, as in the Horse.

The *teres major* is normal in man, but it may attain a very much greater relative size, as in the Mole.

The *subscapularis* is generally in Mammals much as it is in the human subject. It may be considerably smaller, however (as in Cetaceans) ; and by a singular exception it may (as in the

Echidna) exclusively arise from the external surface of the scapula.

The *coraco-brachialis* of man does not normally exhibit the complexity of structure which it may exhibit in some other Mammals. Thus, in addition to the part usually developed in man (namely, that descending to about the middle of the shaft of the humerus), we may have a shorter part inserted above the tendon of the teres major and connected with the capsular ligament (as in the Bonnet Monkey and many other species), and a third part descending right down to the internal condyloid ridge of the humerus, as in the Echidna, in *Lemur*, *Iguana* (Fig. 296), and others.

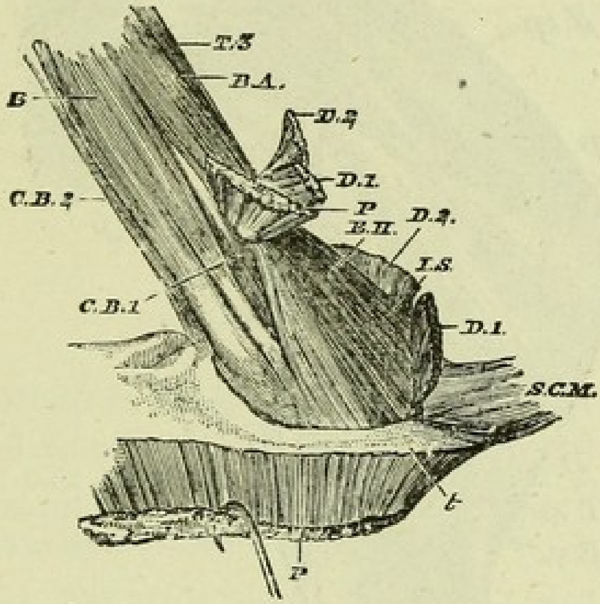

FIG. 294.—MUSCLES OF INSIDE OF RIGHT ARM OF *Iguana* (seen in front), the pectoralis and deltoid being cut short and reflected.

B, biceps; *BA*, brachialis anticus; CB^1 and CB^3, coraco-brachialis; D^1 and D^2, deltoid; *EH*, muscles perhaps answering to the subclavius; *IS*, infraspinatus; *P*, pectoralis; *SCM*, sterno-cleido-mastoid; T^3, triceps.

The *biceps* as it exists in man is a fair exponent of its normal condition, at least in his class. This muscle, however, may arise from but a single head, which may take origin from the scapula only, as in the Pig, or from the coracoid only, as in the Echidna and the Iguana. Its insertion may take place both into the ulna and radius, as in the Pig, and the two tendons of insertion may divide, allowing the brachialis anticus to pass between them, as in the Chameleon. This muscle may arise even from the sternum, as in the Frog.

Brachialis anticus. This is rather short in man. It may be divided into two parts, as in the Agouti. It may be more or less confounded with the biceps, as in *Iguana*, *Menopoma*, and *Menobranchus*.

Triceps. The great extensor of the arm in man, in spite of its size and complexity, is small and simple compared with conditions which may obtain. Thus it may (as in Hyrax) have four heads, and in addition a fasciculus going from the surface of the infra-spinatus to the olecranon, and called the dorso-epitrochlear (Fig. 295, *De.*) It may be very powerful

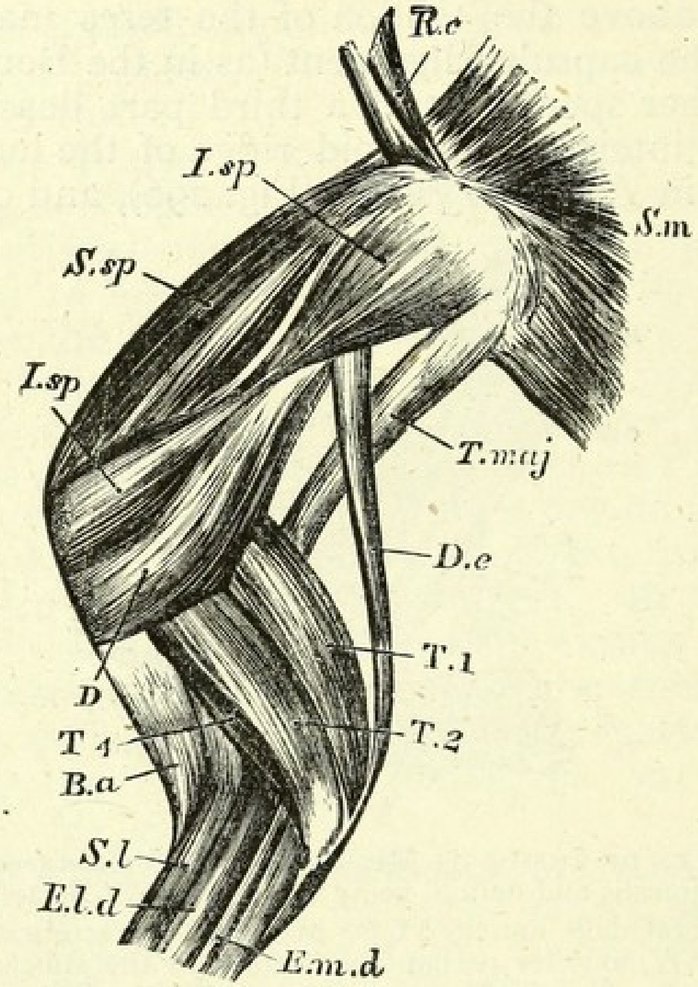

FIG. 295.—MUSCLES OF OUTER SIDE OF FORE-LIMB OF HYRAX.

m, serratus magnus; *Rc*, rhomboideus capitis; *Ssp*, supra-spinatus; *Isp*, infra-spinatus; *D*, deltoid; *Tmaj*, teres major; *De*, dorso-epitrochlear; T^{1}—^{4}, triceps; *Ba*, brachialis anticus; *Sl*, supinator longus; *Eld*, extensor longus digitorum; *Emd*, extensor minimi digiti.

and take origin largely from the scapula, as in the Pig and Echidna, or it may take origin from the coracoid also, as in the Iguana. It may be quite rudimentary, as in the Porpoise.

21. The MUSCLES OF THE FORE-ARM in man attain almost their maximum of complexity. As might be expected, they become greatly reduced in animals the hands of which have little mobility (as Birds and Cetaceans) or have a reduced number of digits. In Birds the actions of the pronators and supinators are modified and limited to opening and shutting the wing, *i.e.* to *ad-* and *ab-duction.*

Pronator teres. This is a nearly constant muscle, being present even in *Menopoma* and *Menobranchus* (Fig. 297). Its size and importance are often relatively greater than in man. It may, on the contrary, be quite absent, as in the Hedgehog and the Horse.

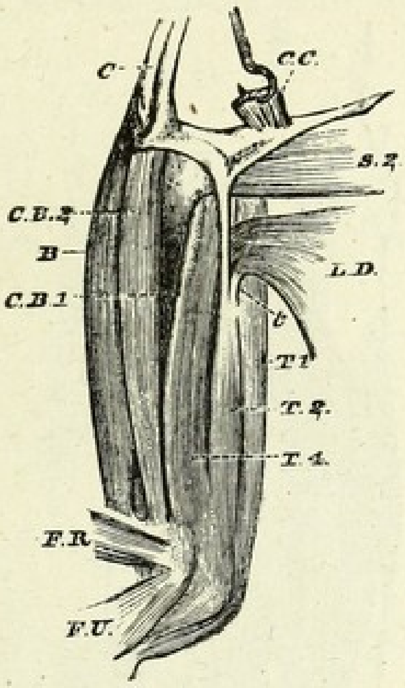

FIG. 296.—MUSCLES OF INSIDE OF RIGHT ARM OF IGUANA.

B, biceps; *C*, sternal margin of coracoid bone; CB^1 and CB^2, two parts of coraco-brachialis; *CC*, costo-coracoid; *FR*, flexor carpi radialis; *FU*, flexor carpi ulnaris; *LD*, latissimus dorsi; S^2, subscapularis; T^1, T^2, and T^4, parts of triceps; *t*, tendon from latissimus dorsi to triceps.

Flexor carpi radialis. This is normal in man, but its insertion may vary in other animals. It may arise from the ulna only (and not from the humerus), as in Birds.

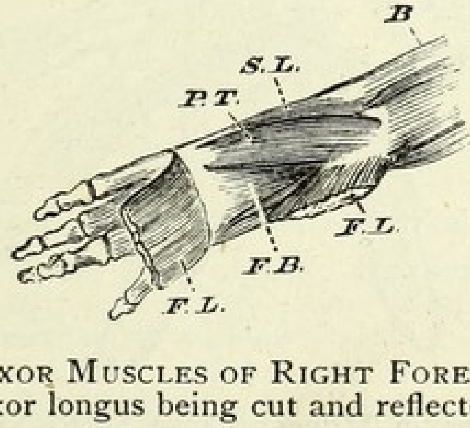

FIG. 297.—DEEPER FLEXOR MUSCLES OF RIGHT FORE-ARM OF *Menopoma*, the flexor longus being cut and reflected.

B, biceps; *FB*, flexor brevis; *FL*, flexor longus; *SL*, supinator longus; *PT*, pronator teres.

The *palmaris longus* is often absent (as *e.g.* in the Hedgehog, in Ruminants, the Horse, &c.), or blends with the flexor digitorum, as in the Echidna, or with the flexor radialis. Its palmar fascia may contain a fibro-cartilaginous disc, as in Hyrax.

The *flexor carpi ulnaris* of man is normal. It may be greatly more complex and divided into four portions, as in the Two-toed Ant-eater, where the pisiform bone is so large.

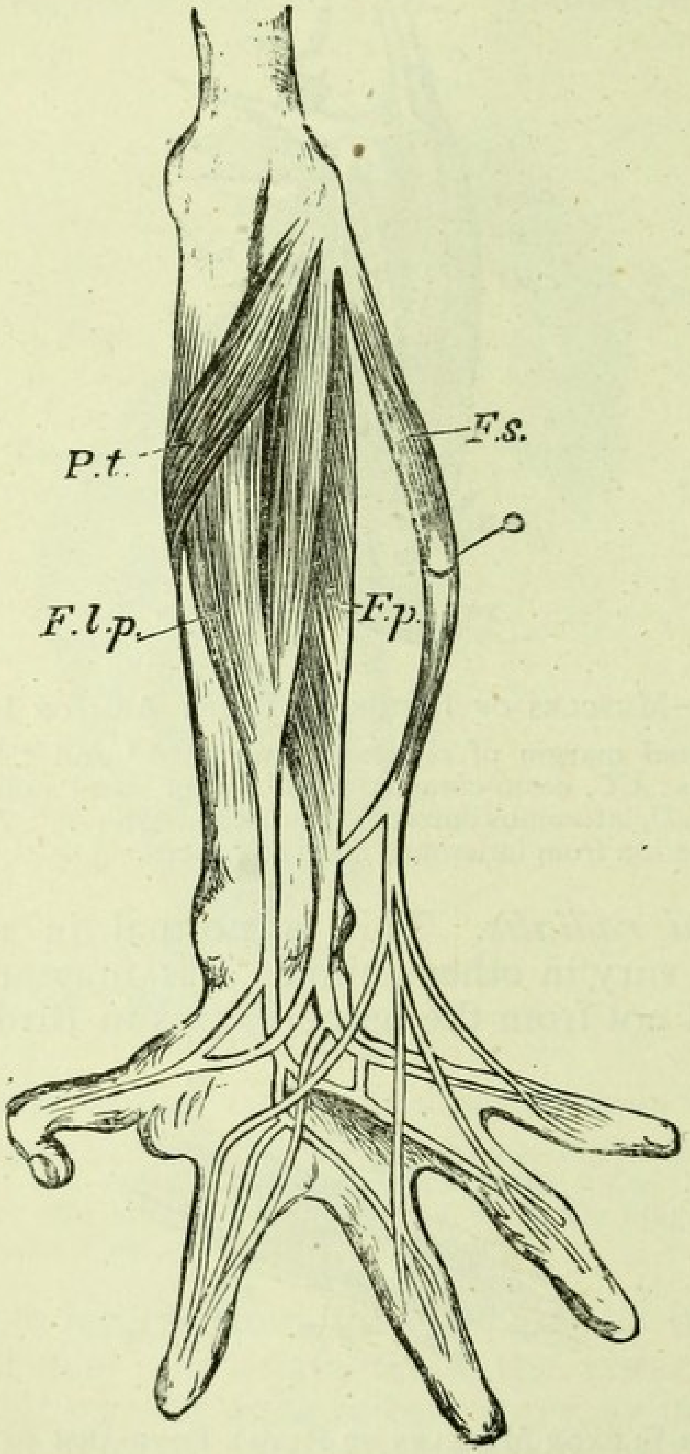

FIG. 298.—LONG FLEXOR MUSCLES AND TENDONS OF THE HAND OF NYCTICEBUS.

Pt, pronator teres; *Fs*, flexor sublimis digitorum; *Fp*, flexor profundus digitorum; *Flp*, flexor longus pollicis.

Flexor sublimis digitorum. This muscle in man presents a degree of distinctness which is by no means constant. It may be united with the flexor profundus in one mass, as in the Kangaroo and Echidna. It may also be confined to the hand, and therefore be a short muscle, as in the Iguana and Chameleon. It is small in Birds.

That symmetrical bifurcation and definite arrangement of the perforated tendons which obtains in man is by no means

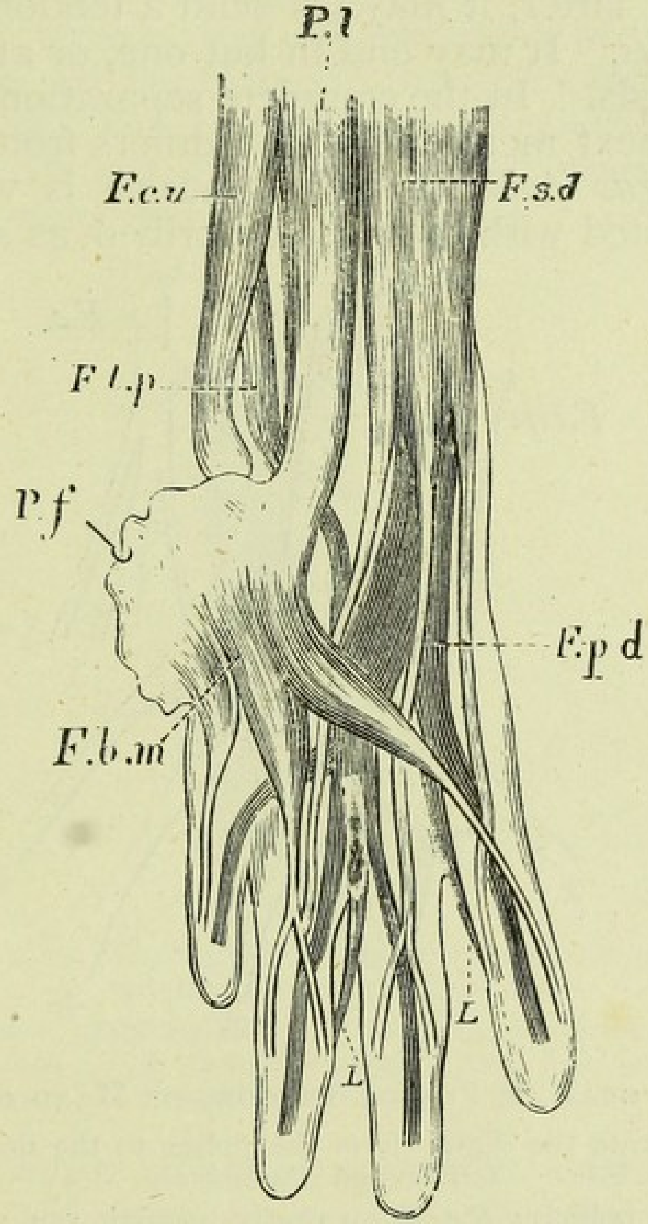

FIG. 299.—FLEXOR MUSCLES AND TENDONS OF FORE-FOOT OF HYRAX.

Pl, palmaris longus; *Fcu*, flexor carpi ulnaris; *Fsd*, flexor sublimis digitorum; *Fpd*, flexor profundis digitorum; *Flp*, flexor longus pollicis; *Pf*, palmar fascia; *Fbm*, flexor brevis manus; *L*, lumbricales.

constant. Thus it is absent in Birds; and in lower Vertebrates (e.g. *Iguana*) this muscle can hardly be said to be inserted by definite tendons. Even in man's own order we may see by the Nycticebinæ how the index digit may fail to have a true perforated tendon, while the imperfect condition of the flexor sublimis may be supplemented (as in Hyrax) by an extra muscle, a peculiar *flexor brevis manus* which takes origin from the palmar fascia.

The *flexor profundus digitorum* in man possesses an exceptional distinctness and subdivision. As has been said, it may be intimately united with the *sublimis*, as it may also be (even in Monkeys) with the *flexor longus pollicis*. When distinct from the latter, it may yet send a tendon to the thumb, as in *Nycticebus*. It may end in but one, or at most two tendons, as in Birds. In the complete separation of this muscle from the one next mentioned, man differs from all the Apes.

Flexor longus pollicis. This muscle is very commonly completely united with that last described, as *e.g.* in *Echidna*,

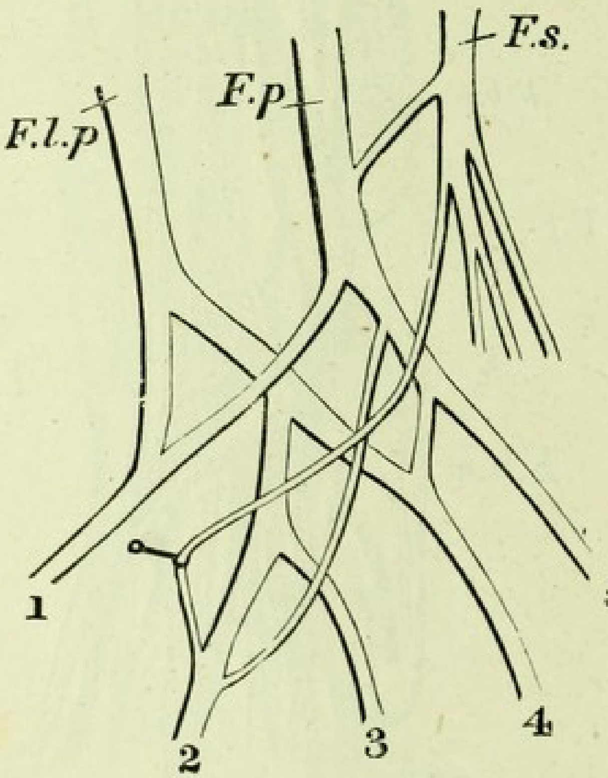

FIG. 300.—DIAGRAM OF FLEXOR TENDONS OF HAND OF NYCTICEBUS.

The numbers indicate the digits (from the pollex to the minimus) to which the tendons go respectively.

F lp, flexor longus pollicis; *F p*, flexor profundus digitorum; *F s*, flexor sublimis digitorum.

Dasypus, and even in the Apes. The two united deep flexor muscles (profundus and longus pollicis) may fail to send any tendon at all to the two or three ulnar digits, as is the case in Bats. When the two deep flexor muscles are distinct, the longus pollicis may send tendons to all the digits, uniting variously with those of the flexor profundus, as in *Nycticebus*, *Loris*, and *Chameleo*. It may send no tendon to the pollex in a form closely allied to man, *i.e.* in the Orang.

Lumbricales. These may be altogether absent (as in Birds, the Hedgehog, and Pig), or there may be but one, as in *Pteropus.* The thumb, on the contrary, may have its own lumbricalis, as in *Dasypus Sexcinctus;* and there may be eight in the hand, as in *Galeopithecus.*

The *pronator quadratus* may be much more elongated than in man, as in the Dog and Cat. It may, however, be completely wanting, as in the Flying Fox and in the Horse. An accessory pronator may be developed (as in the Iguana and Chameleon), arising from the internal condyle and radial border of the ulna, and being inserted into the lower part of the radius between the insertions of the pronator teres and pronator quadratus.

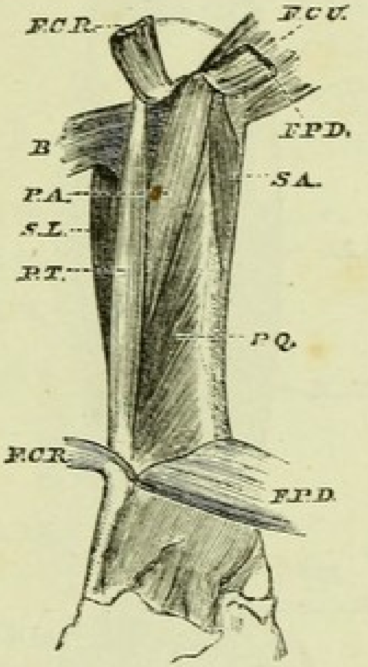

FIG. 301.—DEEP FLEXOR MUSCLES OF FORE-ARM OF *Iguana*, the more superficial ones being cut and reflected.

B, biceps; *FCR*, flexor carpi radialis; *FCU*, flexor carpi ulnaris; *FPD*, flexor profundus digitorum; *PA*, pronator accessorius; *PQ*, pronator quadratus; *PT*, pronator teres; *SA*, supinator accessorius; *SL*, supinator longus.

Supinator longus. This is a very inconstant muscle, as might be expected from its action, which is related to the exceptional mobility of the fore-arm and hand of man. Thus it is totally absent in many animals, *e.g.* the Horse. It may, on the contrary, attain a vastly greater relative size than in man, as in *Bradypus*, where it takes origin from the lower three quarters of the humerus, and is separable into two parts; it is large and double in some Reptiles, *e.g.* the Iguana and Chameleon (Figs. 302 and 303).

The *extensor carpi radialis longior* is exceptionally distinct in man, for in most Mammals it is more or altogether united with the *extensor carpi radialis brevior.*

Anconeus. This muscle, which in man seems to be but a small part of the triceps, may be a very large and very distinct muscle, as in *Dasypus* and *Phoca.*

Extensor communis digitorum. This is exceptionally distinct in man, being often (as *e.g.* already in *Nycticebus*) blended with one or more other extensors. It may be so diminished and short as to extend only from the carpus to the digits, as *e.g.* in *Iguana* and *Chameleo.*

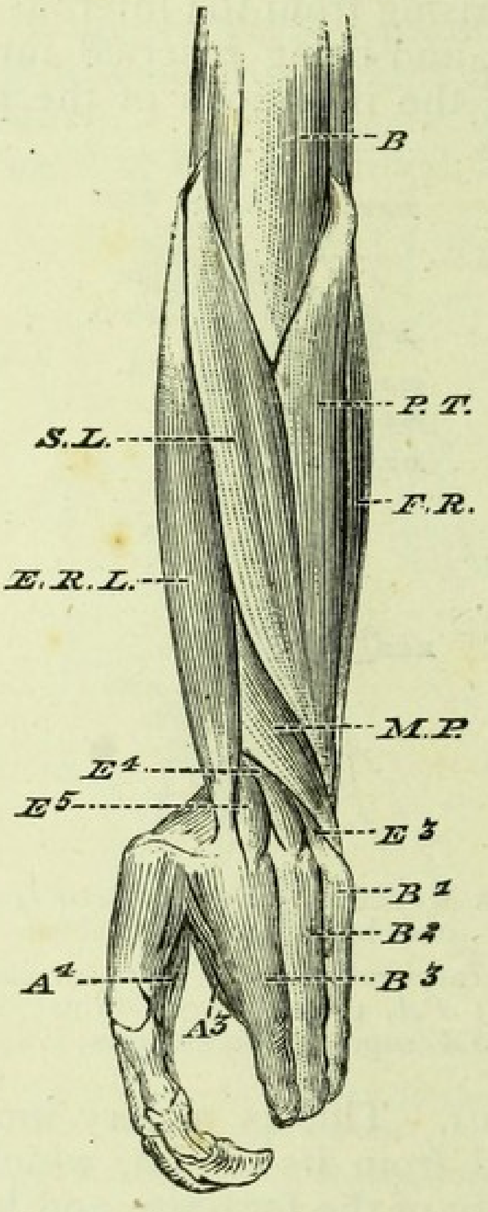

FIG. 302.—RADIAL SIDE OF RIGHT ARM OF PARSON'S CHAMELEON.

A^3, adductor digiti tertii; A^4, adductor digiti quarti; B, biceps; B^1, B^2, B^3, extensores phalangorum; E^3, E^4, E^5, extensores metacarporum; ERL, extensor radialis longior; FR, flexor radialis; MP, extensor metacarpi pollicis; PT, pronator teres; SL, supinator longus.

Extensor minimi digiti. This extensor, which may be absent, may also be present where we might hardly expect to find it. Thus it may be present in forms in which the digitus minimus is entirely absent, *e.g.* the Horse. This fact is less remarkable, however, when it is recollected that the muscle's special destination to the fifth digit is a human but not a Mammalian character. Very often, even in man's own order, this muscle may send tendons to the third and fourth digits also

The *extensor carpi ulnaris*, normal in man, may be much increased in size, as *e.g.* in the Two-toed Ant-eater. It may be diminished—not arising from the humerus—as in some Birds. It may, as in *Iguana*, be united in one with the flexor carpi ulnaris.

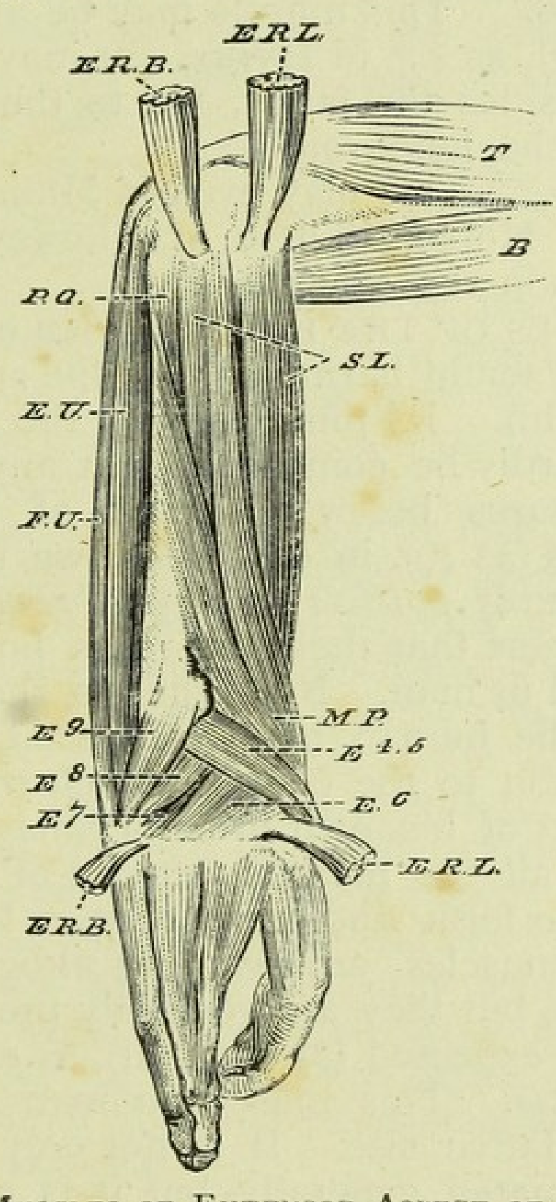

FIG. 303.—DEEPER MUSCLES OF EXTENSOR ASPECT OF RIGHT FORE-ARM OF PARSON'S CHAMELEON, the extensores radiales longior and brevior being cut and reflected.

B, biceps; *E* 4—*E* 9, extensores metacarporum; *ERB*, extensor radialis brevior; *ERL*, extensor radialis longior; *EU*, extensor ulnaris; *FU*, flexor ulnaris; *MP*, extensor ossis metacarpi pollicis: *PQ*, pronator quadratus; *SL*, supinator longus; *T*, triceps.

Extensor ossis metacarpi pollicis. This muscle of man exemplifies a very constant condition, since it exists in animals in which the pollex is entirely absent, as *e.g.* in the Horse.

The muscle may be double and very voluminous, as *e.g.* in the Chameleon. Even in very near allies of man (the Anthropoid Apes) it ends in two tendons, one going to the trapezium, the other to the metacarpal of the thumb.

The *extensor primi internodii pollicis* appears to be exclusively human.

The *extensor secundi internodii pollicis* is often wanting. It may coalesce with the extensor indicis, as in the Dog and Rabbit.

Extensor indicis. This muscle may be absent as well as that last described, as *e.g.* in Hyrax. It may send tendons to other muscles besides the index, viz. to the third, fourth, or fifth digits, as in the Lemuroidea.

Supinator brevis. This may even in Mammals be entirely absent, as in the Horse. There may however be an accessory supinator, as in the Iguana.

22. The MUSCLES OF THE HAND of man of course possess an especial character in harmony with the special perfection of that organ in him. Its muscles, with the exception of the interossei, can hardly be compared with any profit with the muscles of creatures below the rank of Mammals. For though sometimes (as *e.g.* in *Chameleo*) we may meet with a so-called *flexor brevis pollicis* or *flexor brevis minimi digiti*, it is difficult to assert that these are really homologues of the muscles so named in man. Nevertheless, though the muscular condition of the human hand is special, yet its essential type is that common to the class to which man belongs, and especially like that of his own order, Primates, the members of which possess all the manual muscles of man, only more or less different in form and proportion. It may be, however, that these muscles are wanting altogether, as in the Horse and Whale, but they are generally present even where they might not be expected (at least all), as *e.g.* in the Dog.

Opponens pollicis. This muscle in man attains its maximum degree of relative size. It is not only present, though small, in the Primates generally, but it is present in forms quite destitute of an opposable thumb, as *e.g.* in the Dog.

The *adductor pollicis* may be inserted into the index through atrophy of the pollex, as *e.g.* in the Dog.

Palmaris brevis. This muscle is not peculiar to man. It not only exists in his order, as *e.g.* in *Lemur*, but is found even in Marsupials, *e.g.* the Tasmanian Devil. In the Echidna it has been said to take origin from the ulna.

Opponens digiti minimi. This muscle exists not only in man and his order, but even in such forms as the Dog and the Bat.

Interossei. These muscles are very generally present, existing even in the cold-blooded Vertebrates, and their essential nature is that of *flexores breves.* Even in man half of each pair of interossei acts as an extensor, being inserted into the dorsum of the third phalanx ; while half of each pair acts as a flexor, being inserted into the palmar side of the first phalanx. Indeed, it is by a modification of what are *essentially* interossei that some of the small special muscles of the pollex and little finger are constructed, as the *abductor pollicis* and *digiti minimi.*

The distinction between "palmar" and "dorsal" interossei is really unimportant, referring only to the mode of their origin from the metacarpals.

23. In the ABDOMINAL REGION, the body-wall of man is composed of muscular layers such as normally exist in other Vertebrates above Fishes. The muscles may, however, be severally more developed or less developed, or more complex or less complex, than they are in him.

On entering the class of Fishes we lose the superimposed lamellæ of differently directed muscular fibres of which the far greater portion of the abdominal muscles in the higher forms consist. In their place we have exclusively antero-posteriorly directed fibres, and it is as if the rectus muscle had increased vastly and entirely at the expense of the completely aborted oblique muscles. That this is so, seems to be demonstrated by those Batrachians which begin life with so many and close resemblances to Fishes, which subsequently they lose. Thus in the great persistent larva, the Axolotl, we find no truly oblique abdominal muscles, but only as it were a hypertrophied rectus ; while in the rarely attained adult condition (in which it closely resembles the genus *Amblystoma*) we meet with the normal muscular abdominal structure of superimposed oblique lamellæ.

Sometimes the number of these lamellæ is greater than in man : thus the *obliquus externus* may consist of three distinct layers, as *e.g.* in the Iguana.

The *obliquus internus* of man is of moderate development. It may be less developed than in him, as *e.g.* in the common Chameleon. On the other hand it may be much larger, relatively, as in *Iguana*, where it lines the whole of the thorax ; or it may be, as in *Menopoma* and *Menobranchus*, the largest muscle of the body, being continued on forwards and backwards so as to extend from the hyoid to the distal end of the tail.

Transversalis. This third abdominal muscle as it exists in man is normal, but its aponeurotic part may be much

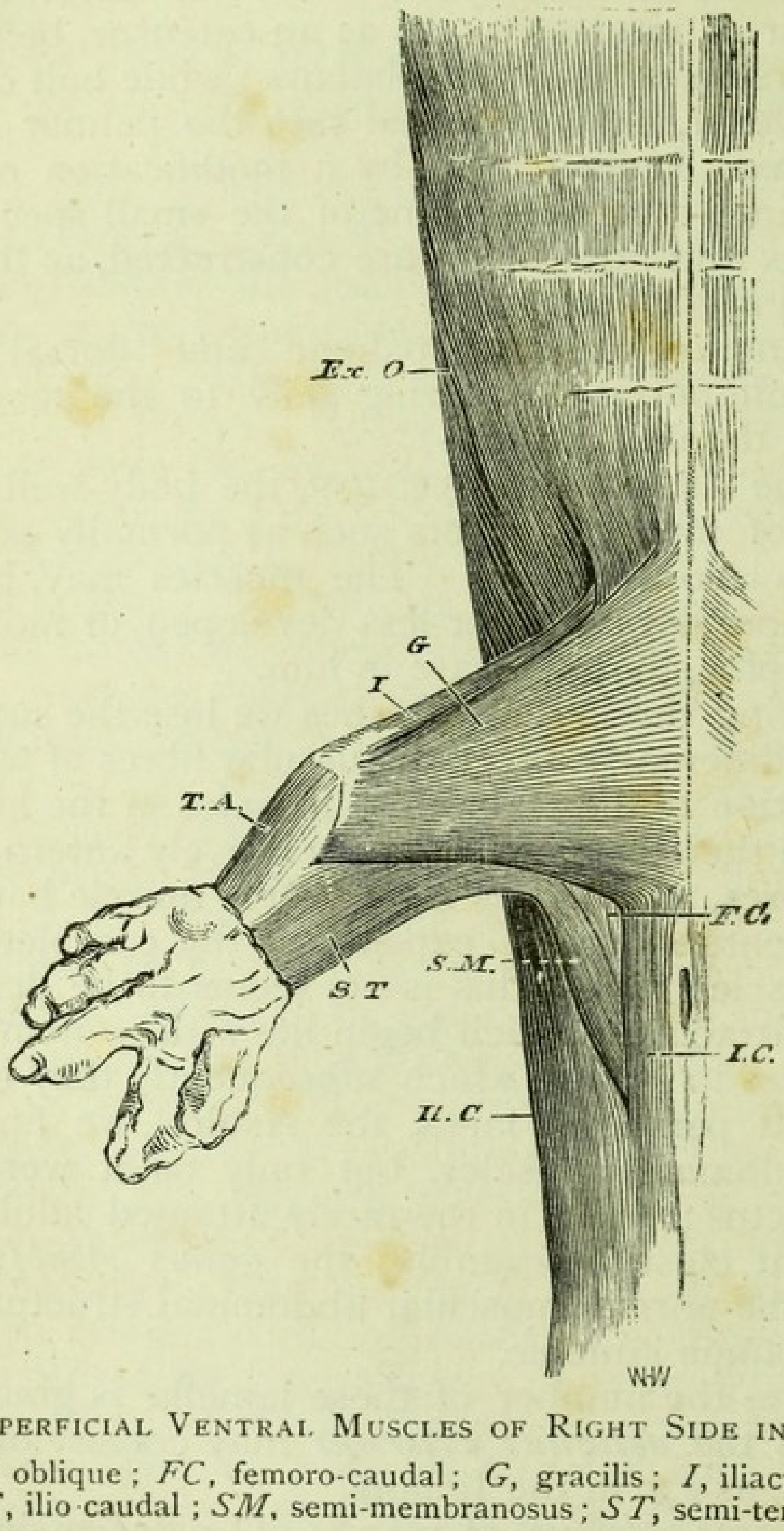

FIG. 304.—SUPERFICIAL VENTRAL MUSCLES OF RIGHT SIDE IN MENOPOMA. *ExO*, external oblique; *FC*, femoro-caudal; *G*, gracilis; *I*, iliacus; *IC*, ischio-caudal; *IlC*, ilio-caudal; *SM*, semi-membranosus; *ST*, semi-tendinosus; *TA*, tibialis anticus.

greater than in him, as *e.g.* in *Iguana*, where its fascia is continued on, even into the neck, within the nerves of the brachial plexus, which pass external to it as the abdominal nerves pass between it and the internal oblique.

Rectus abdominis. The greatest relative size of this muscle is exemplified in the class of Fishes, where it extends in the mid-abdomen from the tail to the pectoral arch, and thence, forwards, to the mandibular symphysis. A complication of division may exist, as we find in the Salamander, where there is a superficial rectus lying, on each side, immediately upon a deeper one.

Even in man's own class this muscle may be very much more developed than in him, as in the Slow Lemur, the Armadillo, and Ornithorhynchus, where it goes to the first rib. The *lineæ transversæ* may be absent, as in the Hedgehog, the Dolphin, and the Hyrax ; or they may be seven in number, as in the Racoon ; or they may be replaced by regular abdominal ribs which subdivide the rectus into a longitudinal series of successive segments, as in the Chameleon.

The pelvic origin of the muscle may be wanting, as in the Cetacea, where it arises (by a long and thin aponeurosis) between the dorsal and ventral muscles of the tail, from the ventral side of the transverse processes of some of the mid-coccygeal vertebræ.

A slip from this muscle may be sent to the humerus, as in some Armadillos and insectivorous Bats.

Pyramidalis. This may be more largely developed than in man, as in the Iguana and in Marsupials and Monotremes, where it arises from the marsupial bones. It becomes enormous in the Ornithorhynchus.

The *quadratus lumborum* is a nearly constant muscle ; it may be distinctly developed in Reptiles, and is large in the Iguana.

The development of the *intercostal muscles* is of course governed by the size and number of the ribs. Thus they may be more or less developed than in man, or they may be completely absent.

24. The *diaphragm.* In the possession of a complete partition, or diaphragm, man agrees with all the members of his own class, but differs from all those of every other class, though in some of the latter it may form an incomplete partition, at the least allowing the apex of the heart to pass into the abdominal cavity, as in the struthious Birds. In man's own class this muscle may vary as to the extent of the central tendon and as to the points of origin and insertion. Thus in the Manatee (which has so many ribs) the obliquity of the diaphragm is so extreme that the thorax extends backwards above the whole length of the abdominal viscera. Very

rarely the diaphragm may contain a sesamoid bone, as in the Camel. There may be no tendinous centre, this being absent in the Porpoise.

In Reptiles (e.g. *Iguana*) a muscle, the *retrahentes costarum*, (which appears to have no representative in man), arises by muscular fibres from the sides of the bodies of the trunk vertebræ, and is inserted by aponeurosis into the inside of the seventh and eighth cervical ribs, and into the seven following ribs. In Tailed-Batrachians (e.g. *Menopoma*) this muscle is very fleshy at its anterior end, and is carried forward beneath the *basis cranii*.

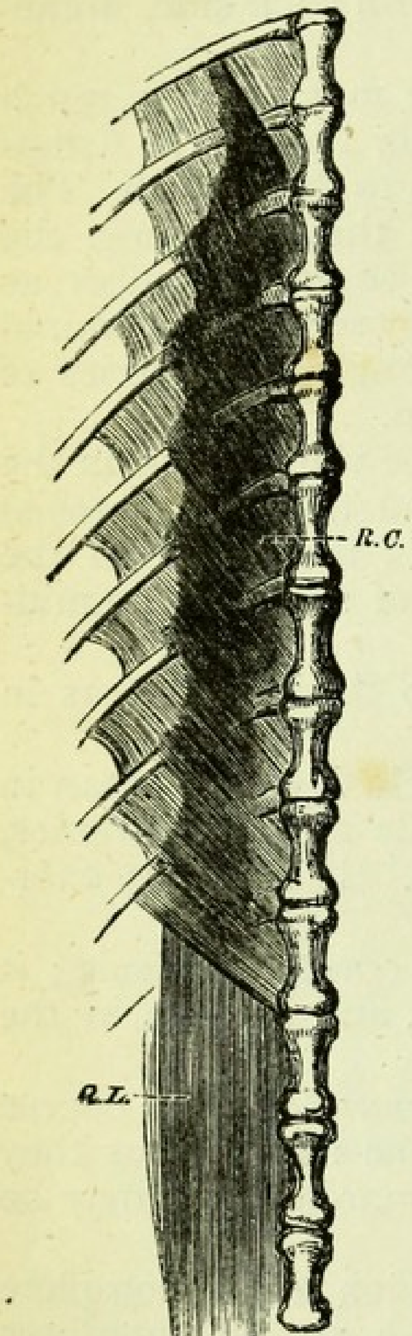

FIG. 305.—SUBVERTEBRAL MUSCLES OF RIGHT SIDE OF IGUANA.

QL, quadratus lumborum; *RC*, retrahentes costarum.

25. Of the MUSCLES OF THE INFERIOR EXTREMITY. The *psoas magnus* may be very much larger relatively than in man (thus it is exceedingly large in the Rabbit and Agouti), or it may be (as in Birds and the common Seal) entirely wanting. It has been supposed that the great muscular mass which in Cetaceans (*e.g.* the Porpoise) and the Seals extends forward beneath the trunk part of the spine from beneath its caudal part, is a psoas. This is not the case, however—it is a *sacro-coccygeus* extraordinarily prolonged forwards.

Iliacus. This muscle may be wanting, as in the Whales and Seals; or relatively enormous, as in the Bats, where it is inserted separately from the psoas, and below the latter. The iliacus (or else the psoas) may extend its origin up to the last two dorsal vertebræ, as in *Nycticebus*.

The *psoas parvus* may be altogether wanting, as in Cetaceans and Birds. It may be as large as the psoas magnus, as in the Pig, or ten times larger, as in the Kangaroo.

A muscle may exist which extends from the coccygeal region of the backbone to the femur, but which has no certain representative in man. Such a muscle is the *femoro-caudal* of Reptiles, Birds, and Tailed-Batrachians. This (*e.g.* in the Iguana and Chameleon) arises beneath the caudal vertebræ, and, though mainly inserted into the femur, sends on a delicate tendon which, passing down, is inserted into the articular cartilage between the femur and tibia.

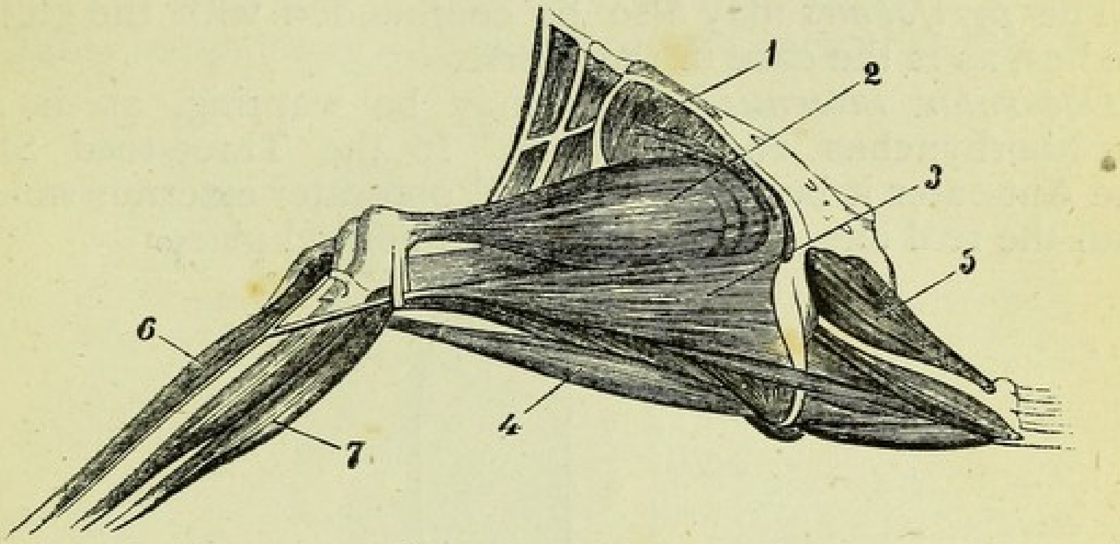

FIG. 306.—MUSCLES OF EXTERNAL ASPECT OF LEG OF AN EAGLE (*Aquila fucosa*).

1, sartorius ; 2, tensor vaginæ femoris (?); 3, biceps ; 4, semi-membranosus ; 5, levator coccygis ; 6, tibialis anticus ; 7, gastrocnemius.

(*After A. Milne-Edwards.*)

Gluteus maximus. This muscle is of very exceptional size in man, directly related as it is to his erect attitude. Nevertheless, it may be yet greater relatively in some quadrupeds than it is in him, as *e.g.* in the Echidna, where it is double, and where part passes from the sacral and coccygeal vertebræ downwards to the ankle, and represents that part of the muscle which in man is inserted into the fascia lata, while another portion with a similar origin is inserted into the femur. The muscle exists in Birds and in Reptiles. In the Chameleon (Fig. 311) it passes from the caudal vertebræ to the tendinous arch going from the posterior margin of the ilium to the tuberosity of the so-called ischium. This muscle may be inserted into the whole length of the femur, as in the Seal.

The *gluteus medius* is very often much thicker and larger than the gluteus maximus. This is the case, *e.g.*, in the Horse, where it is twelve times as big as the maximus. It may arise not only from the ilium but from the sacral and even from the lumbar vertebral spines, as in the Echidna. The muscle appears to be almost a constant one, as it exists, well-developed, in Birds ; and a muscle seeming to represent it, passes from the outside of the ilium to the femur in Reptiles and Batrachians.

The *gluteus minimus* is, when distinct, almost if not quite always smaller than the medius, with which it may be more or less completely blended.

The *pyriformis* may also be confounded with the gluteus medius, as is the case in the Horse.

Obturator internus. This may be wanting, as in the Ornithorhynchus and Echidna. In the Three-toed Sloth and Ant-eater it becomes a second obturator externus smaller than the real one, having quitted its normal place.

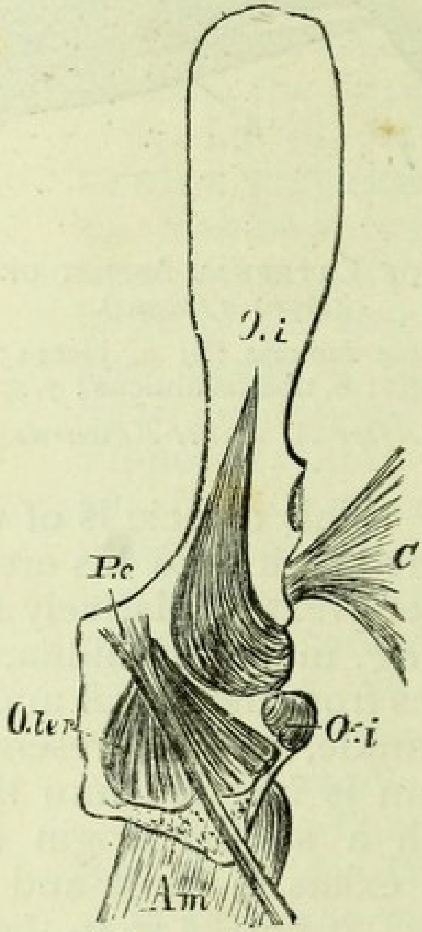

FIG. 307.—INNER VIEW OF RIGHT HALF OF THE PELVIS OF HYRAX.

Oi, obturator internus; *Oter*, obturator tertius; *Pc*, pubo-coccygeus; *C*, coccygeus; *Gi*, gemellus inferior; *Am*, adductor magnus.

The *gemelli* may be wanting altogether, as in the Ornithorhynchus and Echidna. The gemellus inferior may be almost as much developed as the obturator; such, *e.g.*, is the case in the Camel. There may be but a single fleshy strip, as in the Apteryx.

The *quadratus femoris* is an almost constant muscle, though varying as to size, shape, and direction.

The *obturator externus* is also a constant muscle both as to existence and position, being found even in the Frog. A peculiar sort of additional external obturator (but with an anomalous internal origin) may exist, as in the Hyrax, where a third obturator springs from the inner surface of the ischium, close to its junction with the pubes, and which, passing *through the obturator foramen*, is inserted into the trochanteric fossa in common with the obturator externus (Fig. 308).

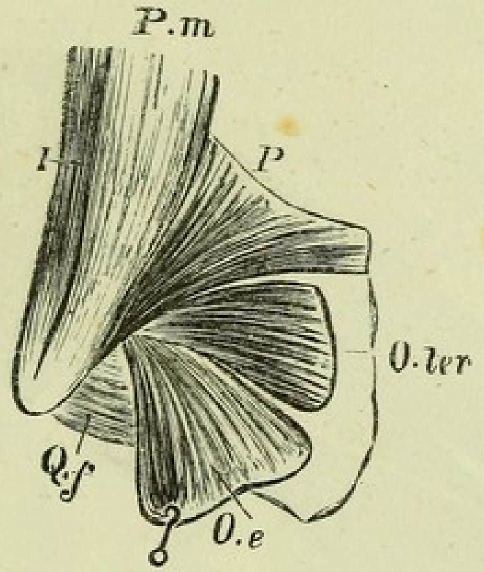

FIG. 308.—RIGHT SIDE OF PELVIS OF HYRAX, seen in front.

I, iliacus ; *Pm*, psoas magnus ; *P*, pectineus ; *Oter*, obturator tertius ; *Oe*, obturator externus (cut and reflected) ; *Qf*, quadratus femoris.

Tensor vaginæ femoris. This may be altogether wanting, as in the true Opossums. It may, on the contrary, be very largely developed, as in the Seals (where it arises from the panniculus carnosus and external oblique) and in the Horse. It may be more or less blended with the gluteus maximus, as in Agouti.

Sartorius. This muscle is generally present in Mammals, though it may be altogether wanting, as in Bats. Its origin and insertion may both differ considerably from what we find to exist in man. Thus, in the Agouti it arises from the ilio-pectineal eminence and the pubic symphysis. It may have two heads (one on each side of the tendon of the psoas magnus), as in the Horse. It may be confounded above with the tendon of the long extensor of the thigh, as in Ruminants. It may arise, as in the Three-toed Sloth, from the lower part of the aponeurosis of the external oblique, and then divide into two parts--one of these being inserted into the femur, the other again subdividing and going to the inside of the tibia above the insertion of the gracilis.

A muscle exists in Reptiles (*e.g.* the Iguana and Chameleon) which may answer to this. It arises from the front pelvic tendinous arch, or from the brim of the pelvis, and is inserted into the peroneal side of the head of the tibia (Iguana), or, bifurcating, sends one branch to the tibia and the other to the inter-articular cartilage (Chameleon). (Figs. 309 and 310, *S.*

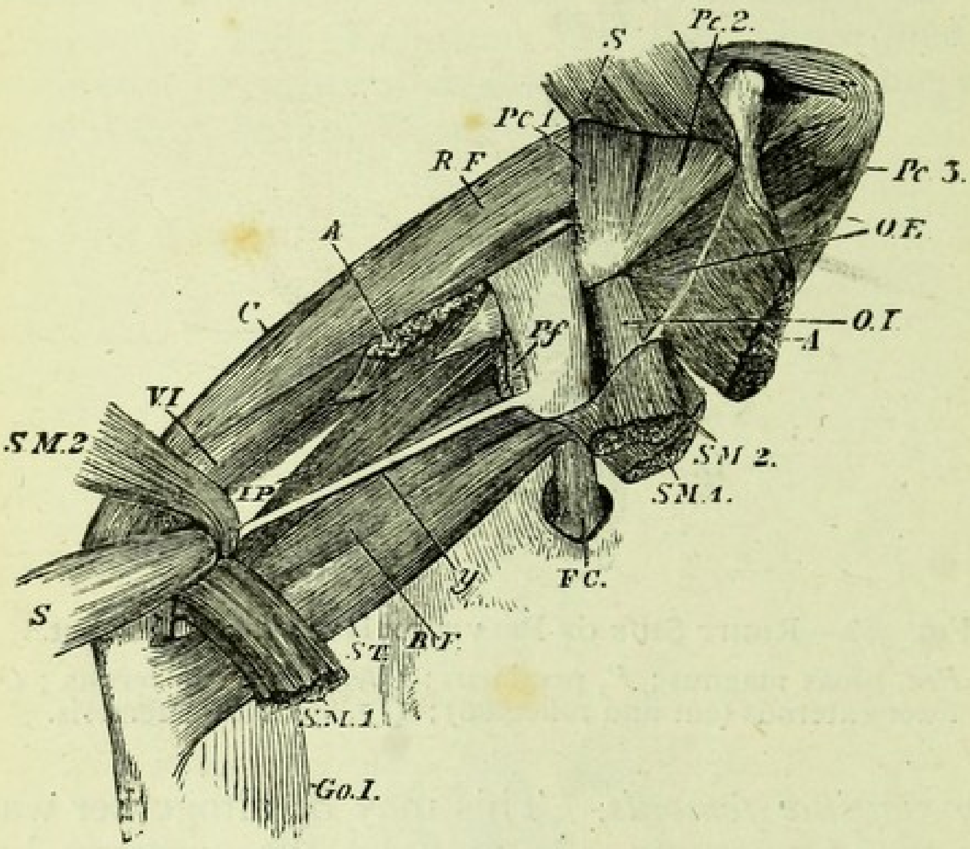

FIG. 309.—DEEPEST MUSCLES OF RIGHT THIGH OF *Iguana*, the more superficial ones being removed.

A, adductor; *BF*, biceps femoris; *C*, crureus; *FC*, femoro-caudal; *GoI*, gastrocnemius internus; *IP*, ilio-peroneal; *OE*, obturator externus; *OI*, obturator internus; *Pc* ^{1}—^{3}, muscles which more or less resemble the pectineus; *Pf*, probably the gluteus maximus; *RF*, part of the great extensor of the thigh; *S*, tibial adductor; *SM* and *ST*, muscles resembling the semi-membranosus and semi-tendinosus respectively; *VI*, vastus internus; *Y*, tendon descending from the tendon of the femoro-caudal to the inter-articular cartilage of the knee-joint.

Quadriceps extensor cruris. The large muscular mass thus named in man, has by no means in him attained its maximum of size and complexity. Even in man's order, e.g. *Lemur*, the portion called crureus, instead of being but a mere imperfectly differentiated part of the vastus internus, is a large and very distinct muscle; while in a nearly allied form, *Tarsius*, the vastus externus is divided into two parts, and the crureus into even three, making with the rectus femoris a sevenfold extensor muscle.

The tendon of a muscle which seems to answer to the rectus femoris may end by uniting with the plantaris, as in the Alligator and in Birds, in which the plantaris is the perforated flexor of the toes, as it is also in the Rabbit.

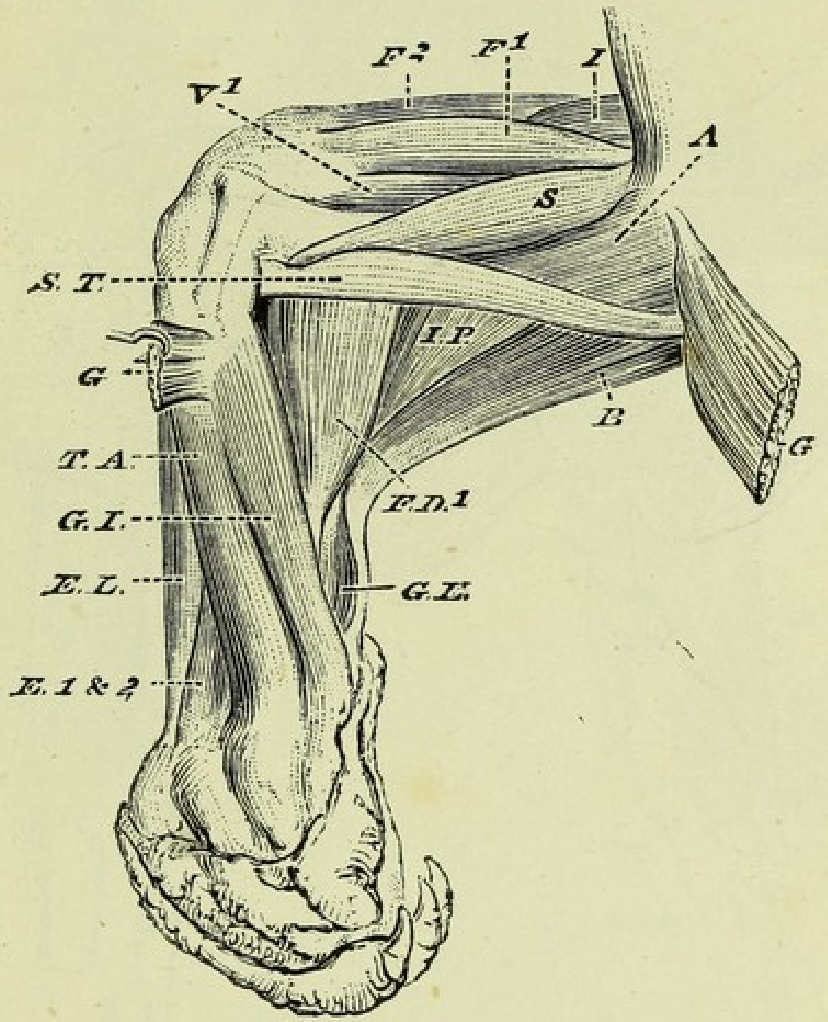

FIG. 310.—DEEPER MUSCLES OF INNER ASPECT OF RIGHT PELVIC LIMB OF PARSON'S CHAMELEON.

A, adductor; *B*, biceps; E^1 and E^2, extensores metatarsorum; *EL*, extensor longus digitorum; F^1 and F^2, rectus femoris; FD^1, flexor longus digitorum; *G*, gracilis; *GE*, gastrocnemius externus; *GI*, gastrocnemius internus; *I*, iliacus; *IP*, ilio-peroneal; *S*, tibial adductor; *ST*, semi-tendinosus; *TA*, tibialis anticus; V^1, vastus internus.

The *vastus internus* may be almost absent, as in the Three-toed Sloth, and the *rectus* may be but imperfectly differentiated from the deeper part of the extensor, as is the case in Bats. The rectus may, on the contrary, be very large and consist of two muscles with distinct origins, as in the *Alligator*, *Iguana*, *Menopoma*, and *Menobranchus*. The vasti and crureus may be absent, as in the two last-named genera.

The *gracilis* in man is an exceptionally narrow and weak muscle, but its insertion may (as in the Three-toed Sloth) occupy almost the whole length of the tibia. This muscle may be intimately blended with an adductor, as in the Pig, or more or less with the sartorius, as in the Coati. It may have a special ridge on the tibia for its insertion, as in *Pteropus*.

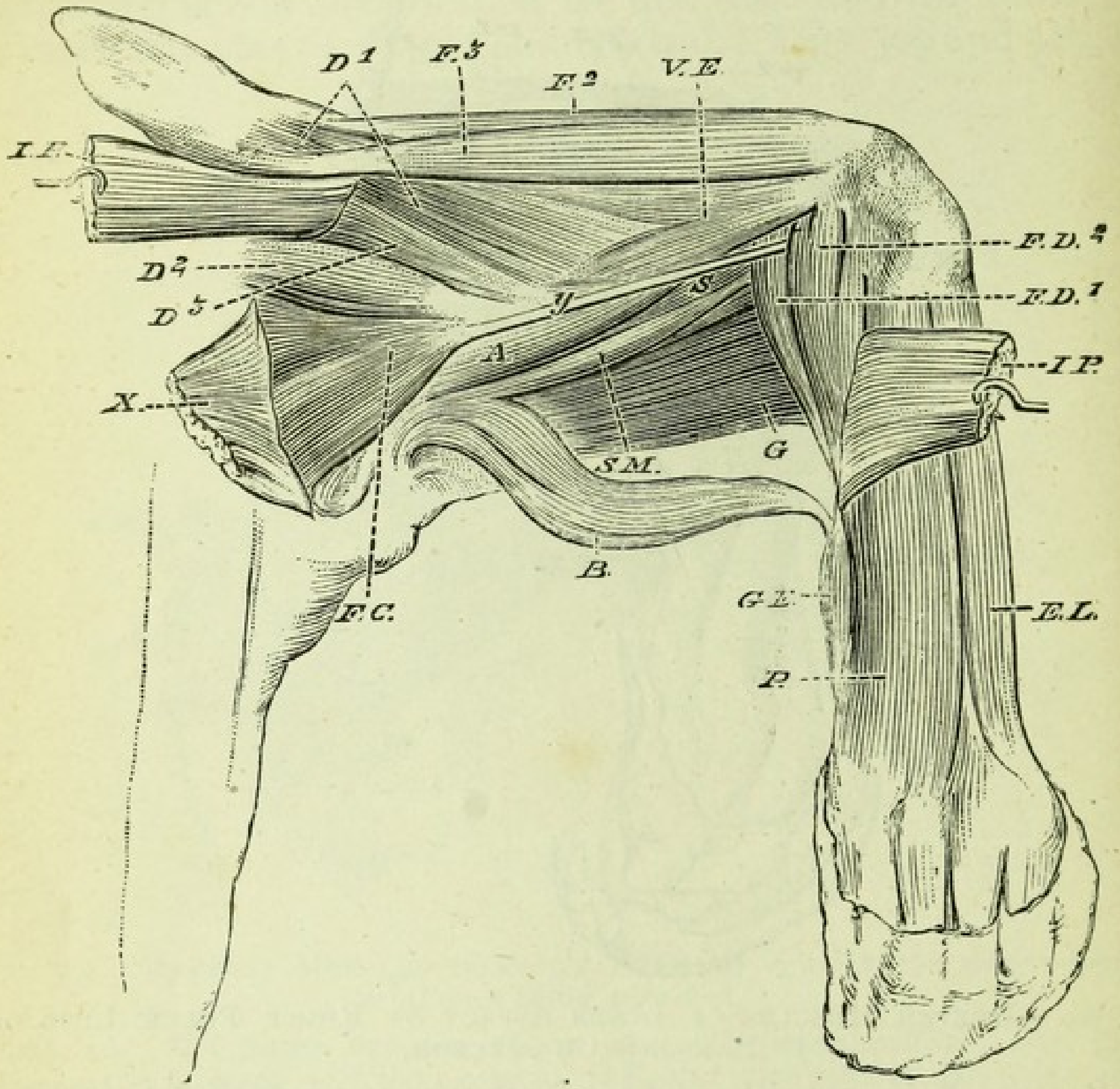

FIG. 311.—DEEPER MUSCLES OF OUTER ASPECT OF RIGHT PELVIC LIMB OF PARSON'S CHAMELEON; the ilio-peroneal cut and reflected.

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.

The *pectineus* and *adductors* of man may exist, in other animals, as muscular masses of very different size and sometimes in different divisions from what they exist in him. The adductors may be extraordinarily small and feeble, as in the Seal.

Biceps femoris. The relative size of this muscle in man is much inferior to its possible development, and in that it

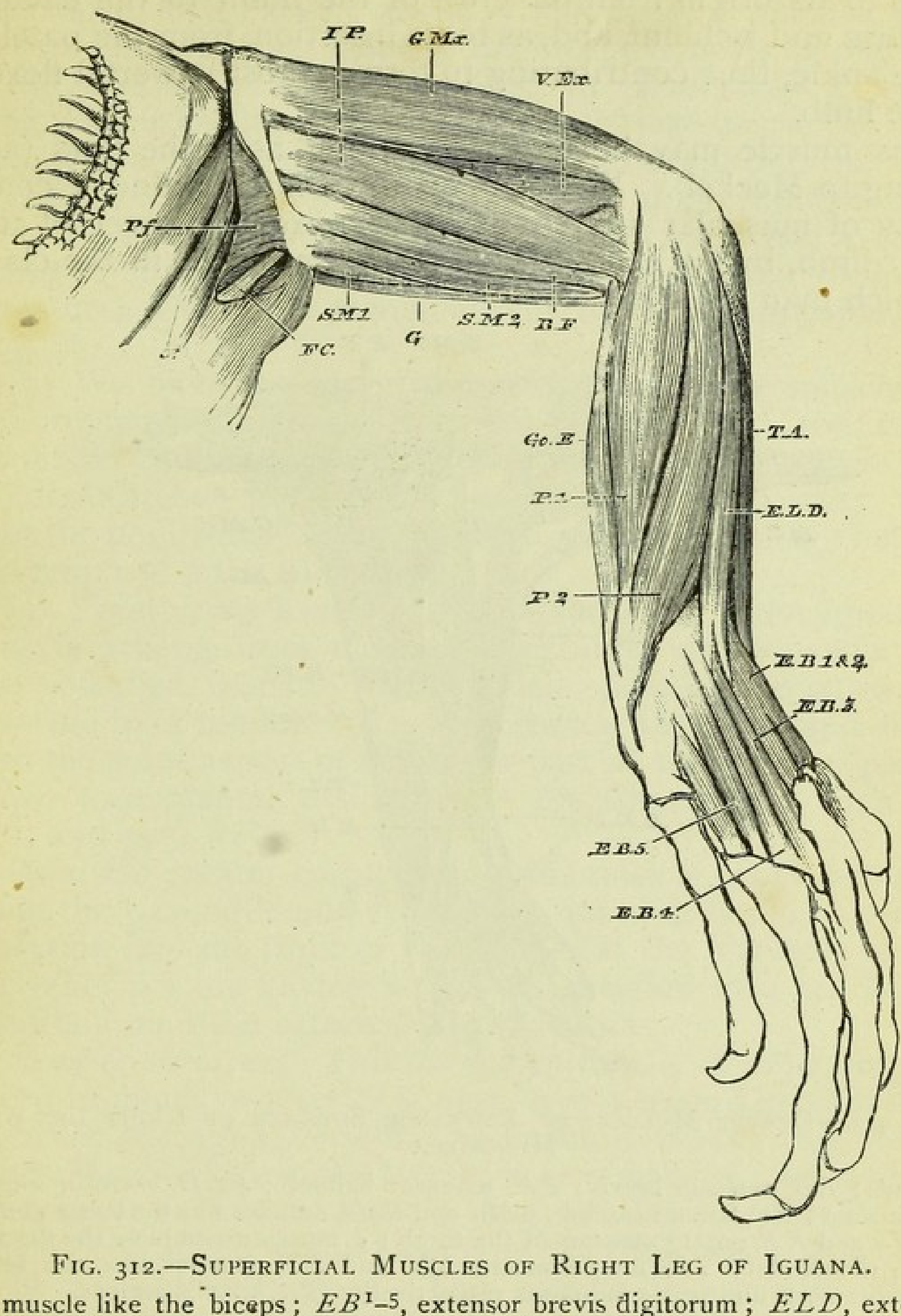

FIG. 312.—SUPERFICIAL MUSCLES OF RIGHT LEG OF IGUANA.

BF, muscle like the biceps; EB^{1-5}, extensor brevis digitorum; *ELD*, extensor longus digitorum; *FC*, femoro-caudal; *G*, gracilis; *GMx*, muscle like the rectus femoris; *Go E*, gastrocnemius externus; *IP*, ilio-peroneal; P^1 and P^2, peronei muscles; *Pf*, muscle resembling in some respects the gluteus maximus; SM^1 and SM^2, semi-membranosus; *TA*, tibialis anticus; *VEx*, vastus externus; *x*, caudal muscle.

has in him a separate head, taking origin from the femur, it is exceptional. Sometimes (as *e.g.* in the Agouti) this muscle combines with the tensor vaginæ femoris and the gluteus maximus to form an almost continuous muscular sheet, extending as to its origin from the crest of the ilium to the caudal vertebræ and ischium, and, as to its insertion, from the patella to the ankle, thus contributing to form a most powerful flexor of the limb.

This muscle may be entirely wanting, as in the Bats (according to Meckel). We may, on the contrary, find a complexity of muscular structure on the peroneal aspect of the pelvic limb, by far exceeding anything met with in the class to which man belongs.

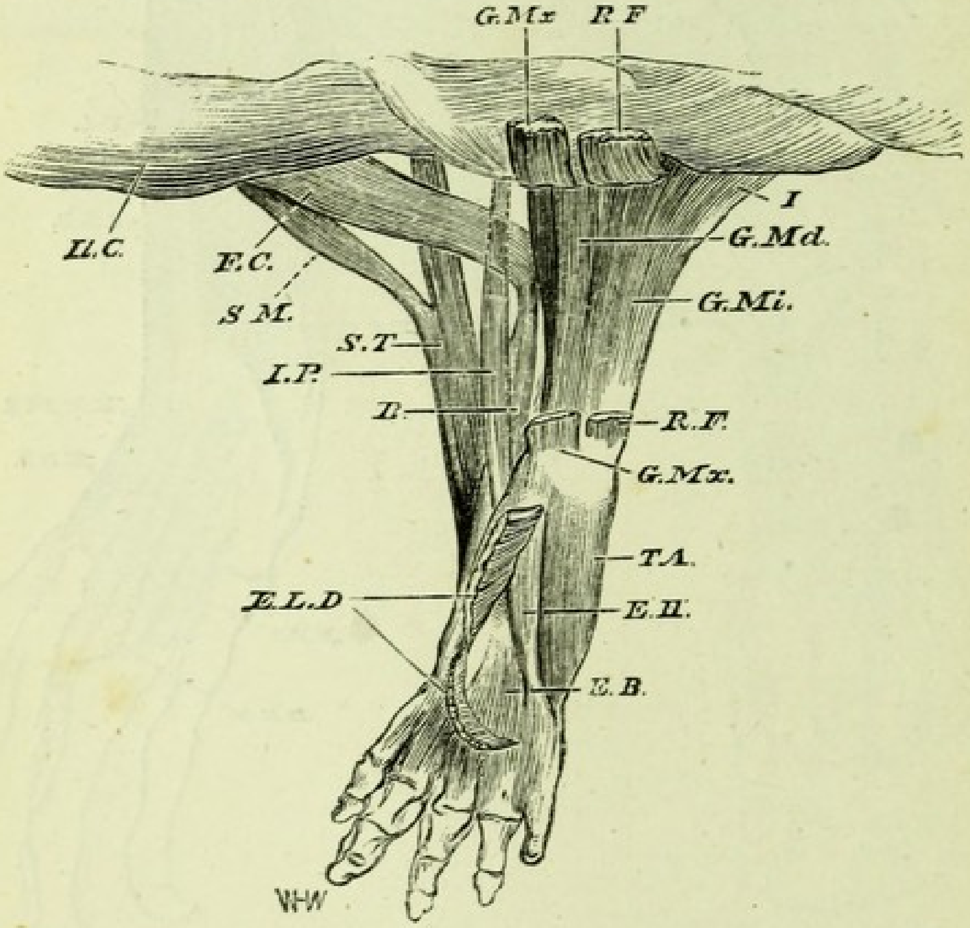

FIG. 313.—DEEPER MUSCLES OF EXTENSOR SURFACE OF RIGHT LEG OF MENOPOMA.

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 *RF*, great extensors of the thigh; *I*, muscle resembling the iliacus; *IlC*, ilio-caudal; *IP*, ilio-peroneal; *SM* and *ST*, muscles like the semimembranosus and semi-tendinosus respectively; *TA*, tibialis anticus.

Thus in some Reptiles and Batrachians we find four distinct muscles which, if not exactly answering to the biceps, may most fitly be noticed in relation with it.

Thus (1) we have a muscle (sometimes called *ilio-peroneal*) extending from the outer side of the ilium downwards to be inserted by a strong tendon outside the upper part of the fibula, or, as in the Chameleon, by a fan-like expansion into the outer side of the fibula. This muscle is very generally developed, as it exists even in *Menobranchus*, where it seems to represent the long head of the biceps femoris of man.

(2) We have sometimes (*e.g.* in Urodeles) a muscle springing from the shaft of the femur, just below the insertion of the femoro-caudal, and itself inserted into the fibula. It seems to answer to the short head of the human biceps femoris, and if so it is interesting to note at what a remote distance from man we find a striking analogy to human structure, which yet seems absent in the Sauropsida (Fig. 313, *B*).

(3) We have the large and very remarkable muscle (the femoro-caudal, before described) arising from the caudal vertebræ, and inserted by a very strong tendon into the great trochanter, but giving off a delicate tendon passing down into the popliteal space to the inter-articular cartilage between the femur and the tibia.

(4) Finally, we have in some Reptiles (*e.g.* the Iguana) a muscle arising from the tendinous arch, which passes from the so-called ilium to the so-called spine of the pubis, and inserted by a tendon (passing between the tibia and fibula) into the front aspect of the upper part of the tibia, or passing down to a plantar ossicle, as in the Chameleon (Figs. 309, 312, and 317, *BF*).

By a still greater complication this muscle may be doubled, as in the Crocodile and Alligator; one part having a twofold insertion into the front of the tibia and the plantaris muscle, the other portion having a twofold insertion into the head of the fibula and the external gastrocnemius.

Semi-tendinosus. This is exceptionally slender in man. Even in man's own order it may have a second head of origin from the coccygeal vertebræ, as in the Aye-aye; and often in other Mammals (*e.g.* the Horse) it is very large. Its insertion, even in Apes, is lower than in man and Bats. In the Dog and Cat it is attached to the middle of the tibia, while in the Bear it is inserted still lower. This muscle may partly end in a tendon becoming confluent with that of the internal gastrocnemius, as in Birds. A muscle which may be the semitendinosus, but which otherwise has no representative in man, springs from the tendinous arch referred to in speaking of the biceps, and is inserted into the upper part of the tibia by a tendon common to it and to the gracilis in the Iguana, or above it into the inter-articular cartilage in the Chameleon.

The *semi-membranosus* of man is small compared with that of some other animals (*e.g.* of the Horse and Ruminants), where it is enormous; the rump-steak of the butcher not consisting, as often supposed, and sometimes taught, of the gluteus maximus, but of the semi-tendinosus and semi-membranosus.

Sometimes (as *e.g.* in the Kangaroo) this muscle is more or less completely blended with the semi-tendinosus. On the other hand it may, as in Hyrax, not only be enormous, but also arise by two heads (one from the ischium, the other from the caudal vertebræ), and have an insertion into the condyle of the femur as well as into the tibia.

This muscle may, as in the Iguana, consist of two parts; one attached to the back of the leg, embracing the inner head of the gastrocnemius—some fibres passing beneath the internal lateral ligament; the other inserted, in common with the sartorius, into the peroneal aspect of the tibia (Fig. 317).

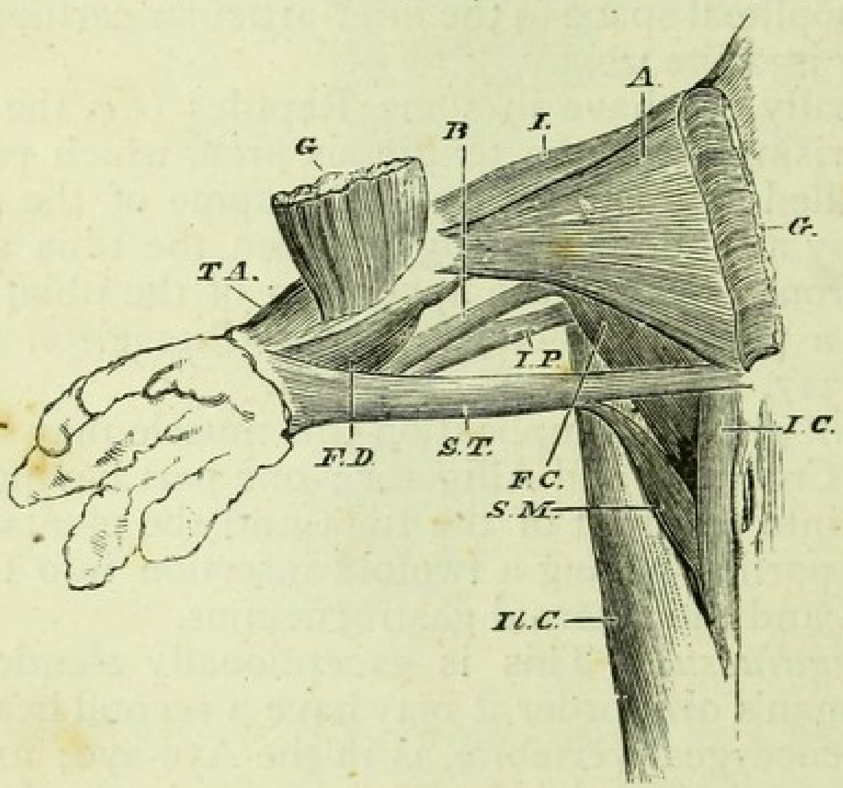

FIG. 314.—DEEPER MUSCLES OF FLEXOR SURFACE OF RIGHT HIND LEG OF MENOPOMA.

A, adductor; *B*, biceps; *FC*, femoro-caudal; *FD*, flexor digitorum; *G*, muscle in position more or less like the gracilis—it is cut and reflected; *I*, muscle like an iliacus; *IC*, ischio-caudal; *IlC*, ilio-caudal; *IP*, ilio-peroneal; *SM* and *ST*, muscles like the semi-membranosus and semi-tendinosus respectively; *TA*, tibialis anticus.

It may, together with the preceding muscle, present what appears to be an anomalous condition, as in the Tailed-Batrachians (e.g. *Menopoma*), where a muscle (Fig. 314, *SM*) takes origin from beneath the caudal vertebræ and blends with a second muscle (Fig. 314, *ST*), which, springing from the ischium, passes downwards and ends in a fascia outside the lower part of the flexor longus digitorum.

The semi-tendinosus and semi-membranosus may, as in the Seal, be represented by a muscle arising from the anterior coccygeal vertebræ and inserted into the tibia, some tendinous fibres going to the plantar surface of the hallux.

26. Of the MUSCLES OF THE LEG. The *tibialis anticus*, even in Anthropoid Apes, may have the part going to the hallux so distinct as to be reckoned a distinct muscle—sometimes called the *abductor longus hallucis*. It may be unquestionably double, as in the Echidna. It may have a double origin and a single insertion, as in the Agouti. It may be inserted into the second metatarsal, as in Hyrax; and may be altogether wanting, as in the Pig. It is inserted into the tarso-metatarsal bone in Birds, and is situate quite on the inner aspect of the leg in *Chameleo* (Fig. 310). It exists down to the Urodeles, being apparently double even in *Menobranchus*. It may arise from the femur, as in the Frog.

Extensor proprius hallucis. This muscle may be altogether absent, as in the Hare and Rabbit. It may even in man's order (*e.g.* in *Lemur*) take origin from the tibia as well as from the fibula. The tendon of the muscle may be inserted into the second digit instead of into the hallux, which is the case in the Echidna. Often this muscle is blended with the extensor longus digitorum pedis. A muscle may exist in Reptiles (*e.g.* in *Chameleo*) arising from the lower two-thirds of the front of the fibula and inserted into the dorsum of the second metatarsal; and even in Urodeles (e.g. *Menopoma* and *Menobranchus*) a small muscle arises from the lower part of the fibula and goes to the hallux, or, in the absence of this, to the second digit.

The *extensor longus digitorum pedis* may spring from the femur, as in the Pig, Hare, Hyrax, and Horse. Apart from diminution in the number of the tendons resulting from the atrophy of certain digits, the subdivision and distribution of the ultimate tendons may vary even in the Primates. It may end in two tendons only, going respectively to the second and third metatarsal bones (as in the Iguana), or it may be inserted exclusively into the third, as in *Chamæleo Parsonii.*

The *extensor brevis digitorum pedis* is subject to great variations in extent and arrangement in different animals. It may be altogether wanting, as in the Hare and Rabbit. It may be reduced to a minimum, as in the Horse; or be split up into three portions, as in the Iguana; or into seven small muscles all arising from about the central tarsal ossicle or the end of the fibula, and going to the five metatarsals, as in *Chamæleo Parsonii*—with other almost endless variations in different forms.

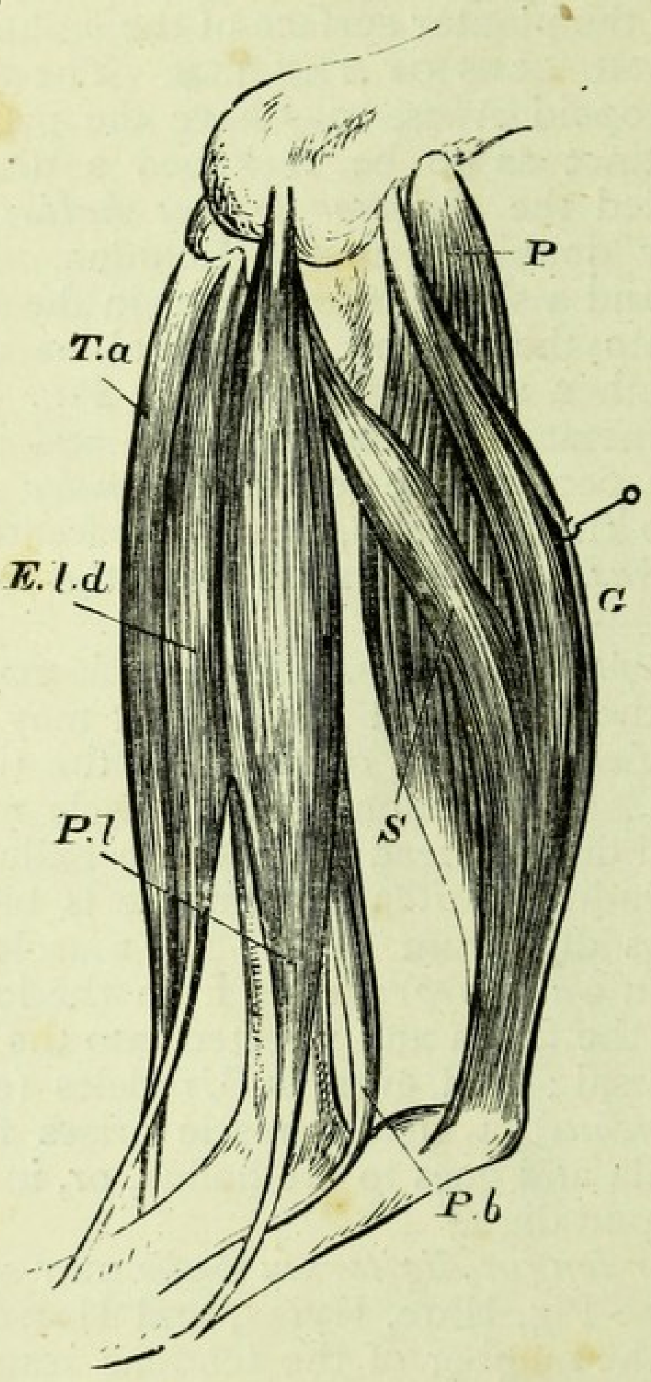

FIG. 315.—MUSCLES OF LEFT HIND LEG OF HYRAX.

Ta, tibialis anticus; *Eld,* extensor longus digitorum (the origin of this muscle ought to have been carried up to the femur); *Pl,* peroneus longus (this muscle ought not to have been made to arise from the femur); *Pb,* peroneus brevis; *S,* soleus; *G,* gastrocnemius; *P,* plantaris.

The *peronei* muscles may be much more largely developed than in man. Thus in the Hare four such muscles, not including the peroneus longus, send tendons to the second, third, fourth, and fifth digits respectively. They are muscles, however, which are largely developed only in the Mammalian class.

The *Peroneus tertius* is, amongst Primates, exclusively human. Sometimes (*e.g.* in some individual Guinea-pigs) the tendon of the peroneus longus will pass down in front of the malleolus, and so simulate a peroneus tertius. It is said to be present in the Wombat.

Peroneus longus. This may be altogether wanting, as in the Horse, and apparently in all below Mammals. Its tendon may, as in Hyrax, pass outside the malleolus instead of behind it. The muscle may take origin in part from the femur (as in the Ox and Opossum), and be inserted into the naviculare or second metatarsal.

Peroneus brevis. This may be altogether absent in man's class, as in the Agouti. It may be reinforced by peronei muscles going to the fourth and fifth digits (and termed *peronei quarti et quinti digiti*), as in *Lemur.* These have exceedingly slender tendons.

In the Rabbit, a muscle which springs from the front of the tibia and passes behind the *internal* malleolus, going to the extensor tendon of the second digit, has been called the *tibialis secundi digiti.* This does not exist in man.

The *gastrocnemius* is generally a double muscle, but there may be only a single head and belly, as in the Echidna. The muscle may be very slender, and quite insignificant in size when compared with the flexor longus digitorum, as is the case in *Loris.* The muscle may be divided into two lateral portions, and become connected with quite other muscles, as is the case in the Iguana and Chameleon. Thus, in the Iguana the external head (which, contrary to the condition in most Mammals, is larger than the internal) ends below in a membrane which forms, as it were, perforated tendons for the digits. This head may arise, as in the Chameleon, by a tendon from the inter-articular cartilage.

The internal head of the gastrocnemius of the Iguana is closely connected with the insertion of the semi-membranosus, and receives a tendon from the biceps. The internal head may arise from the tibia only, as is the case in Parson's Chameleon.

This muscle (Fig. 314) may be absent or included in the semi-tendinosus (as in *Menopoma*), which in the sole becomes superficial to the flexor digitorum. The tendo Achillis, instead of being strongly inserted into the calcaneum, may in many forms, *e.g.* Hyrax, pass behind and beneath it into the plantar fascia.

The *soleus,* even in *Nycticebus*, has lost its tibial attachment, is entirely muscular, and blends with the gastrocnemius. It may (as in the Agouti) arise from the tibia only; it may be inserted into the astragalus, as in the Ornithorhynchus; or it may be wanting, as in the Pig, Hyæna, Seal, and others.

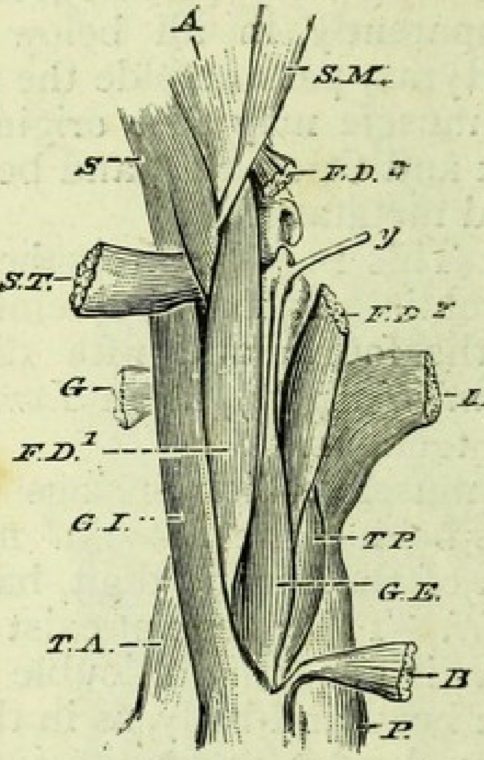

FIG. 316.—DEEPER MUSCLES OF BACK OF RIGHT LEG OF PARSON'S CHAMELEON.

B, biceps; *FD*[1], flexor longus digitorum; *FD*[2], flexor tertius digitorum; *G*, gracilis; *GE*, gastrocnemius externus; *GI*, gastrocnemius internus; *IP*, ilio-peroneal; *P*, peroneus; *S*, tibial adductor; *SM*, semi-membranosus; *ST*, semi-tendinosus; *TA*, tibialis anticus; *TP*, tibialis posticus; *y*, tendon of femoro-caudal.

Plantaris. This muscle may be altogether absent, as in the Wombat. It may however be present as a large belly, and arise from the outer condyle of the femur, as in the Pig and Rabbit. It may also, as in the same animals, end in an expansion which runs along the sole and becomes the perforated tendons of the digits. This muscle may be connected even with the pelvis by the intervention of the rectus femoris, the tendon of which is continued on into it, not only in Birds but also in the Alligator. It may be intimately connected with the outer head of the gastrocnemius, and fleshy bellies may replace the perforated tendons, as in the Iguana.

The *popliteus* may arise from the head of the fibula, even in man's own class, *e.g.* in the Echidna, where it extends far down the leg, and the same origin exists in the Iguana

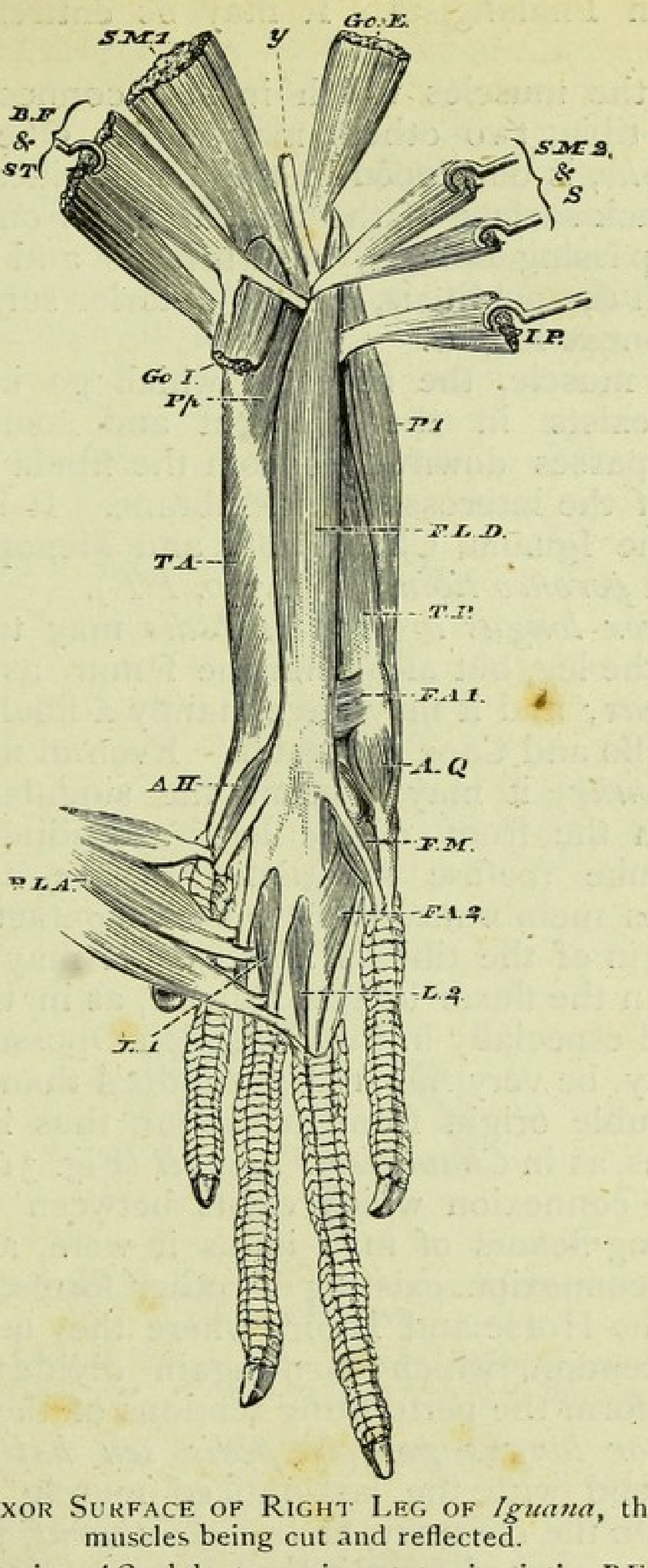

FIG. 317.—FLEXOR SURFACE OF RIGHT LEG OF *Iguana*, the superficial muscles being cut and reflected.

AH, abductor hallucis; *AQ*, abductor ossis metatarsi quinti; *BF*, biceps femoris; *FA*^{1} and *FA*^{2}, flexor accessorius; *FLD*, flexor longus digitorum; *FM*, flexor minimi digiti; *GoE*, gastrocnemius externus; *GoI*, gastrocnemius internus; *IP*, ilio-peroneal; *L*^{1} and *L*^{2}, lumbricales; *P*^{1}, peroneus; *PLA*, plantaris; *Pp*, popliteus; *S*, tibial adductor; *SM*^{1} and *SM*^{2}, semi-membranosus; *ST*, semi-tendinosus; *TA*, tibialis anticus; *TP*, tibialis posticus; *y*, tendon of femoro-caudal.

and in Birds. It may extend almost the whole length of the fibula, as in Phalangista. It may be entirely wanting, as in Bats.

Besides the muscles which in man connect together the fibula and tibia, two others may exist. One of these, the *rotator fibulæ*, is developed in the Lemuroidea. It extends from the back surface of the tibia to the front of the fibula, the fibres passing obliquely downwards and outwards. It lies beneath the popliteus, and its anterior surface is covered by the peroneus longus.

Another muscle, the fibres of which go in the opposite direction, exists in the Wombat and some other allied forms. It passes downwards from the fibula to the tibia in the place of the interosseous membrane. It is largely developed in the Iguana, Chameleon, and Menopoma, and has been called *peroneo-tibial* (Fig. 320, *PT*).

The *flexor longus digitorum pedis* may take origin not only from the leg, but also from the femur, as in *Nycticebus* and *Pteropus;* and it may have mainly a fibular origin, as in the Armadillo and Cape Ant-eater. Even in man's own order (*e.g.* in *Lemur*) it may present the singular character of origin from the front of the leg, ascending between the rotator fibulæ (before mentioned) above and across the interosseous membrane, so as to be in contact with the posterior margin of the tibialis anticus. It may be very much smaller than the flexor longus hallucis, as in the Agouti and Hyrax, and especially in the Virginian Opossum. It may, on the contrary, be very much larger indeed than the other, and have a double origin from the femur, thus indeed forming two muscles, as in *Chamæleo Parsonii* (Fig. 316). The generally slight connexion which exists between the tendons of the two long flexors of man is, as it were, a remnant of a far closer connexion existing in other forms, as (in the extreme) in the Horse and Tapir, where they unite completely into one tendon, which then again divides, in the latter animal, to form the perforating tendons of the digits.

The *flexor longus pollicis pedis seu hallucis* may thus entirely blend with the last-noticed muscle as regards its tendon. On the contrary, as in *Cyclothurus*, it may be more completely separated from it than in man. It may be entirely absent, or it may be very large as in the Three-toed Sloth. It may be present but send no tendon to the hallux, as in the Orang, in which it springs from the outer condyle. It may appear on the front of the leg, as in *Chamæleo Parsonii.* It is still distinguishable, even in Tailed-Batrachians, as in *Menopoma* and *Menobranchus*.

The *tibialis posticus* may be entirely absent, even in man's class, as in the Rabbit and Tapir. It may be very strong, and inserted into the astragalus, as in the Echidna, or run on to the ento-cuneiforme, as in *Lemur*. The muscle may be very greatly developed, as in the Beaver and Wombat. It is constant, as not only in Reptiles (e.g. *Iguana* and *Chameleo*), but even in the Frog it exists (inserted into the astragalus), though it does not seem distinct in Tailed-Batrachians.

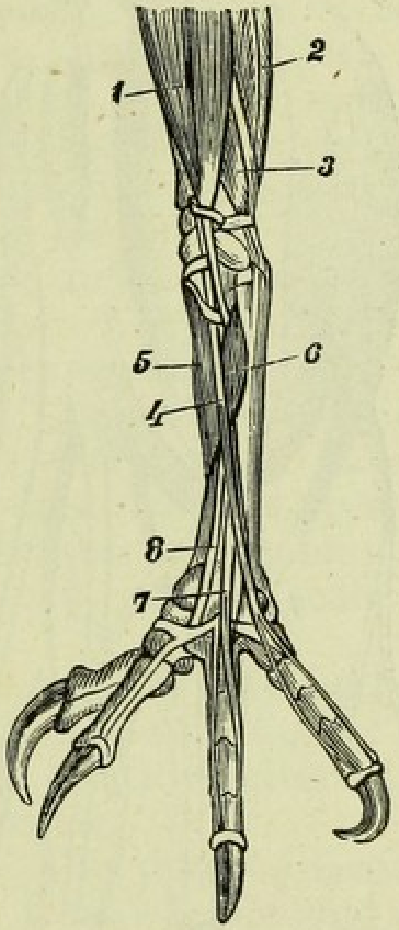

FIG 318.—TENDONS AND MUSCLES OF EXTENSOR ASPECT OF FOOT OF EAGLE (*Aquila fucosa*).

1, tibialis anticus; 2 and 3, peronei; 4, tendon of extensor longus digitorum pedis; 5 and 6, extensor hallucis; 7 and 8, tendons going to third and fourth digits respectively.

(*After A. Milne-Edwards.*)

27. The MUSCLES OF THE FOOT of man possess of course, like its skeleton, special characters in harmony with the peculiar function of that organ as the sole support and agent of progression of an erect and relatively large and ponderous body. These muscles, like those of the hand, can for the most part be profitably compared only with those of man's

own class, but even in that they may be reduced to a minimum, as in the Horse. The foot may be largely developed, with four elongated and prehensile digits, and yet have very little muscular tissue, as in Birds. Some leg muscles may be present, and yet there may be no foot-muscles, as is the case in *Lialis Burtonii*.

The *abductor pollicis pedis seu hallucis* is often absent, as in the Horse; yet it exists in both Reptiles and Batrachians, as, *e.g.*, in the Chameleon and the Frog.

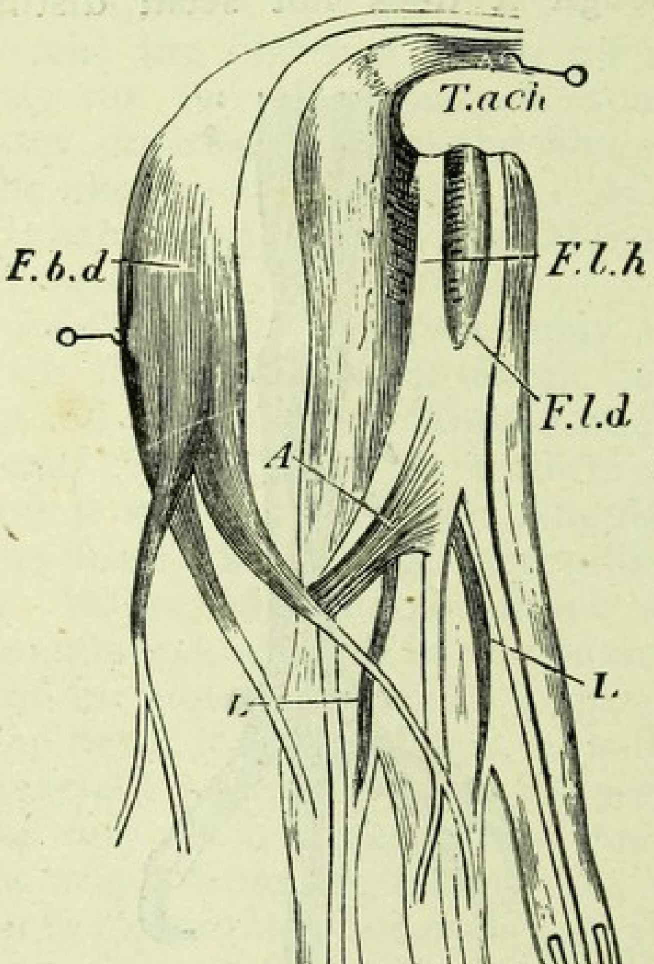

FIG. 319.—MUSCLES AND TENDONS OF SOLE OF HIND FOOT OF HYRAX.

Tach, tendo Achillis; *Flh*, tendon of flexor longus hallucis; *Fld*, tendon of flexor longus digitorum; *Fbd*, flexor brevis digitorum, with one of its perforated tendons cut through and the whole muscle drawn to the one side to expose the deep flexor tendons; *A*, accessorius; *L*, lumbricales.

Flexor brevis digitorum. This may be absent, and then is often replaced by the plantaris, as, *e.g.*, in the Pig and Rabbit. It may arise exclusively from the surface of the deep flexor tendon, as in *Nycticebus*, and in no member of man's order but man himself does it arise from the os calcis only.

The *abductor digiti minimi* may be absent, as in many forms, *e.g.* the Horse; or it may be very large and aided, as in Lemur, by another muscle (which is generally absent in man) called *abductor ossis metatarsi quinti*, and which, arising from the calcaneum, is inserted into the fifth metatarsal.

Flexor accessorius (Fig. 319). This may be altogether wanting, not only in such forms as the Horse, but even in members of man's order, e.g. *Lemur*. It may be inserted by muscular fibre into the perforating flexor tendons, or it may furnish most of the long flexor tendons, as in *Hapale*. It is a more constant muscle than might be expected, as it is to be found in the Iguana. It may be enormous, with three fleshy bellies, as in the Three-toed Sloth.

Lumbricales (Fig. 317). These muscles may be quite absent, as in the Hedgehog, Seal, and Three-toed Sloth, and in Birds. They may be represented by tendons only, as in the Horse. They may be only two in number, as in the Agouti and Hyrax; or they may be as many as six or seven in number, as in Bats. They are more constant structures than might have been expected, as they are found in Reptiles, *e.g.* in the Iguana and Chameleon, and in the Frog, though they do not seem to be developed in Tailed-Batrachians.

Flexor brevis pollicis pedis. As need hardly be said, this muscle may be entirely absent. It may, however, reappear when wanted, low down in the scale, *e.g.* in *Chamæleo Parsonii* and the Frog.

The *adductor pollicis pedis* may perhaps be represented in the Frog by a large muscle taking origin between the elongated tarsal bones; but it is inserted into the naviculare and accessory tarsal ossicle.

Transversus pedis. This may be larger relatively than in man, as in the Apes. It may be blended with the muscle last noticed, as in *Lemur*, and it may, as in many forms (*e.g.* the Horse) be absent altogether. Muscular fibres may be inserted into the metatarsal of the hallux, thus forming an *opponens hallucis*, as in the Orang; and a similar structure may be still further developed in a singularly low form, *i.e.* the Frog, where an opponens muscle is supplied to each of the four inner digits, and this in addition to *transversi* muscles, which extend between the first and second, second and third, and third and fifth digits respectively.

A *flexor brevis digiti minimi pedis* may be present, as in Apes, or it may be absent, as in many forms. It exists in the Iguana (Fig. 317) and Chameleon. In addition to this an *abductor minimi digiti pedis* may exist in man's order, *e.g.* in *Lemur*, and also in the Frog, where it is largely developed.

Interossei. The interossei of the human foot are peculiar, as in all Apes (even in the Gorilla) they resemble in arrangement the interossei of the hand, owing to the arising of the fibular interosseus of the second digit from the middle meta-

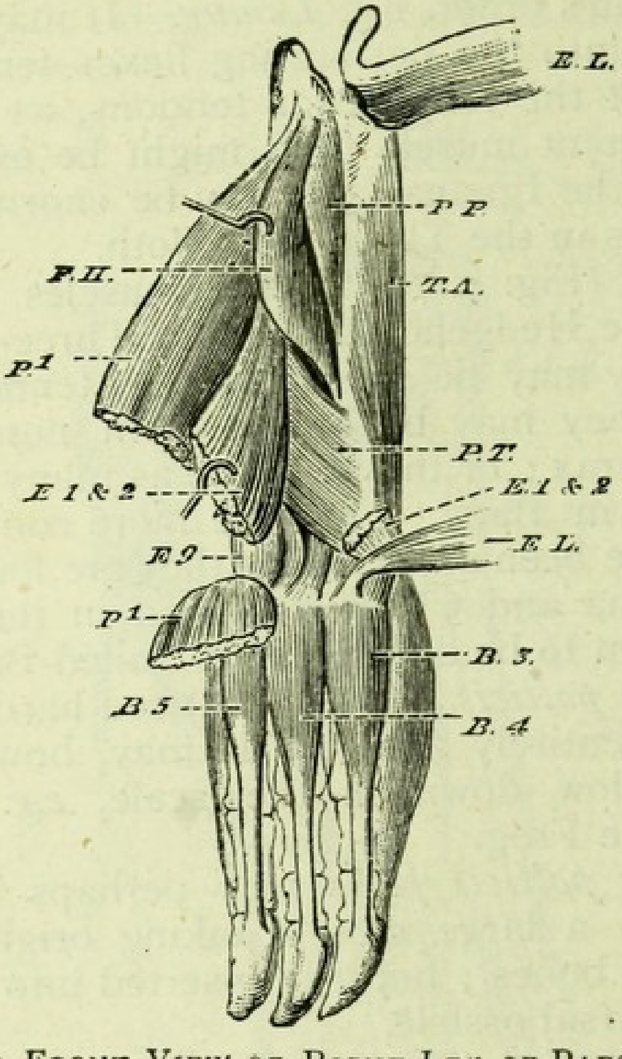

FIG. 320.—DEEPER FRONT VIEW OF RIGHT LEG OF PARSON'S CHAMELEON.

B^3–B^5, extensores phalangorum ; E^1 and E^2, E^9, extensores metatarsorum ; *EL*, extensor longus digitorum ; *FH*, flexor hallucis ; P^1, peroneus ; *PP*, popliteus ; *PT*, peroneo-tibial ; *TA*, tibialis anticus.

tarsals on the dorsal side of the tibial interosseus of the middle digit. They are nearly constant muscles, and are largely developed even in Batrachians, as in the Frog, which animal possesses indeed a singularly rich myological furniture of the foot. In the Bat there are two interossei to each toe. They may consist, as in the Horse, of two small muscles, one being placed between the styliform and the large metacarpal on each side.

28. Thus, as might have been expected, man's muscles follow the type exhibited by his class and order, still pre-

senting normally certain special peculiarities, though such differences are not absolutely constant, owing to individual variation. Thus he is peculiar in the following points: He has an *extensor primi internodii pollicis* and a *peroneus tertius.* He has the *flexor longus pollicis* disconnected from the *flexor profundus digitorum.* His *soleus* arises both from the tibia and the fibula, and his *flexor brevis digitorum* springs entirely from the calcaneum. Moreover, the peroneal *interosseus* muscle of the second toe arises on the dorsal side of the origin of the tibial interosseus of the middle toe.

29. In comparing the myology of the pectoral and pelvic limbs of man, we find that owing to the diverse flexure of the two limbs, the extensors are placed forwards in the lower limb, backwards in the upper one. The flexors of the upper limb easily bend the hand upon the arm, but those of the lower cannot bend the foot upon the leg; at the most they straighten it—a motion called "extension," but which is really an imperfect "flexion."

The serial homology of the appendicular muscles can only be understood by imagining the limbs in their primitive position, with the extensors outwards, the flexors inwards. Then we have the supra- and infra-spinatus and the iliacus, the extensor carpi radialis and tibialis anticus, all pre-axial; the sub-scapularis and glutei, the peronei and the extensor ulnaris, all post-axial.

The muscles inserted into the post-axial tuberosity of the humerus lie in man on the inner side of the thoracic girdle (sub-scapular surface), those inserted into the post-axial trochanter of the femur lie on the outer side of the pelvic girdle (gluteal surface). Their positions may, however, correspond unmistakably, as in the Echidna.

Muscles inserted into the pre-axial trochanter arise within the ribs. No muscles so arising (except in Chelonians) go to the pre-axial tuberosity.

In man there are no common flexors or extensors taking origin in the hand in the upper limb, and none such springing from the femur in the lower one; but we have seen that both these conditions may exist in other animals.

In the arm, the long flexors of the thumb and digits arise on the same side of the limb as that to which they are distributed.

In the leg, they arise from the opposite side to that of their distribution, their tendons crossing each other.

In the arm, the extensor muscles cross each other; in the leg they do not.

The *triceps* is the great extensor of the arm, the *quadriceps* of the leg.

The *peroneus longus* and *flexor accessorius* are leg muscles which resemble nothing in the arm of any animal. An interlacing like that which takes place between the flexor tendons of man's foot, is absent in his hand, but is present in the hand of some animals, *e.g. Nycticebus.*

An *opponens* present in the pollex is wanting in the hallux in man, but the hallux of the Orang is furnished with an opponens.

30. The muscular system is that in which the plastic power which co-adapts structure and function is pre-eminently conspicuous, as is well shown in the Frog's foot and the wing-edge muscle of Bats and Birds. Thus homologies become difficult to determine, being disguised by such an abundance of adaptive modifications.

Though there is a general correspondence between the development of the skeleton and of the muscles which clothe it, yet sometimes skeletal parts may be greatly increased in size, while at the same time there is a simultaneous decrease in the relative development of the muscles annexed, as in the hand of Bats and the thorax of Chelonians.

The endo-skeletal muscles may be divided into (1) *axial,* and (2) *appendicular.*

The axial muscles, like the skeleton (as we saw in the Sixth Lesson), may be subdivided into three groups: (1) *epaxial*, (2), *paraxial*, and (3), *hypaxial.* They have a primitive relation to vertebral segments, but this relationship is lost, and the segments coalesce antero-posteriorly, in non-gill-bearing Vertebrates.

The epaxial group includes the inner part of the erector spinæ and its continuations, attaining perhaps its maximum of development in the Flat Fishes, *e.g.* the Sole, and its minimum in Fishes like Ostracion and in the Tortoises.

The paraxial group includes the outer part of the erector spinæ and its continuations, also the scaleni, levatores costarum, intercostals, abdominal muscles, rectus, and *outer* lower tail muscles of Tailed-Batrachians and at least many Fishes. This group is at its maximum of differentiation in Serpents.

The hypaxial group includes the recti antici, longus colli, sub-vertebral muscles of Birds, Serpents, and Tailed-Batrachians, also the psoas and femoro-caudal and the muscular masses investing the chevron bones of Cetaceans, and the lower caudal muscles of some Fishes, *e.g.* the Sole.

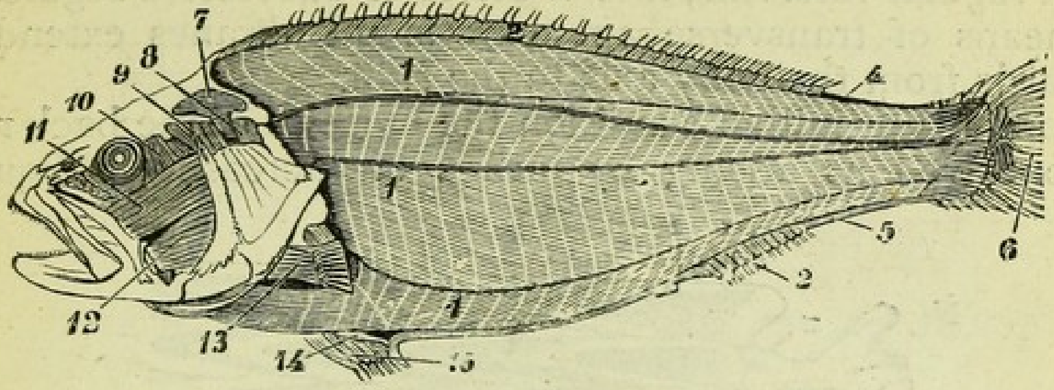

FIG. 321.—SUPERFICIAL MUSCLES OF THE PERCH.
The fin-rays of all the fins are cut short off.

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; 4, 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 which by its contraction closes the jaws; 13, superficial muscles of the pectoral fin; 14 and 15, muscles of the ventral fin.

The muscles which invest that special division of the hypaxial skeleton, the splanchnapophyses, also constitute a group by themselves, connecting together the hyo-branchial arches and the jaws, the stylo-hyoid, constrictors of the pharynx, buccinator, &c.

The appendicular muscles may be divided into those of the limb-girdles and those of the appended limb.

They may be at a maximum of size in relation to the axial system, but simple and without any special differentiations, as in the Rays. They may be at their maximum of differentiation, though less in relative or even in absolute size, as in the highest Mammals.

This differentiation begins to be indicated directly we ascend from the class of Fishes, as we have seen that even in the Tailed-Batrachians definite flexors, extensors, pro- and supinators already appear; and these distinctions, once established, persist up to man himself, though with increasing complications. Special complications, especially of the muscles of the pelvic limb, have been found by us to be developed in Reptiles, such as we do not find in man's own class.

Considered independently of the bony skeleton, the muscular system may, as its simplest expression, be conceived as a fleshy, antero-posteriorly extended envelope of the body, cut up, at regular intervals, into a series of successive segments, by means of transverse aponeurotic membranes extending outwards from the body axis to the skin.

From this primitive condition the muscles of the back may be conceived as arising by means of increasing obliquity,

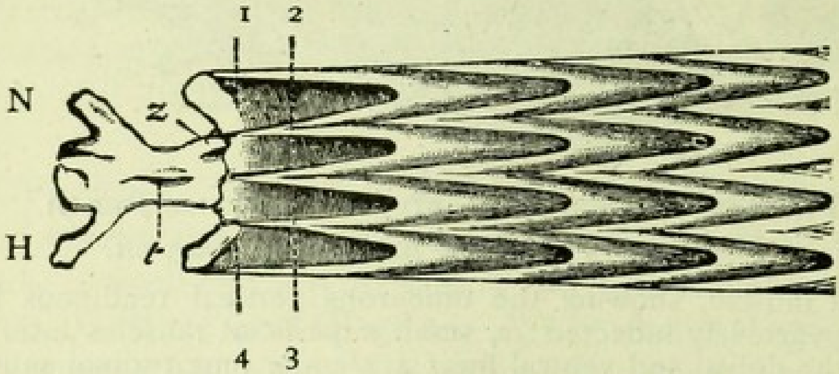

FIG. 322.—DIAGRAM OF CAUDAL MUSCLES OF RIGHT SIDE OF TAIL OF *Iguana*, showing the obliquity of the aponeurotic intersections of the muscular portions which are themselves drawn out into cones yet preserving a numerical relation to the supporting vertebræ.

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 ; 4, ventral series of cones.

conical prolongation, and partial detachment (from muscle) of the aponeuroses, together with condensation of their produced ends till the latter become firm tendons, directed more or less obliquely forwards—the muscular fibres, in the meanwhile, taking slightly different directions at different depths.

The muscles of the abdomen may be conceived as arising through atrophy of the transverse aponeuroses (of which the *lineæ transversæ* of the rectus are the last remains) and differentiation of the muscular mass into superimposed sheets of differently directed fibres.

The muscles of the limbs may be conceived[1] as arising as conical sheaths of muscular fibres investing protruding limb-rudiments, and becoming divided and annexed to successive limb-segments as such limb-rudiments become developed and segmented—finally assuming the form of a median and two lateral groups of muscles both on the extensor and flexor surfaces of each limb.

[1] As has been suggested by Professor Humphrey, F.R.S.

LESSON IX.

THE NERVOUS SYSTEM AND ORGANS OF SENSE.

1. THE NERVOUS SYSTEM may perhaps be considered the primary and most important of all the systems of parts of which the body is composed, because it dominates and directs, as it were, the actions of the other parts. Moreover, sometimes at least, it serves as a criterion in settling disputed homologies of structures which belong to other systems. Thus, the question as to what bone in one animal answers to what bone in another animal is often determined, as in the case of some cranial bones, by the several relations of such bones to a certain nerve; and the same kind of test may not improbably serve to determine many muscular homologies also.

2. The PRIMARY STRUCTURES of which the nervous system is composed (i.e. *nerve-fibres* and *ganglionic corpuscles*) have been described in the "Elementary Physiology," Lesson XII. §§ 16 and 19, and the nervous system as a whole has also been sketched in Lesson XI. of the same work. Therein have been duly set forth its main component parts —the brain and spinal marrow (or cerebro-spinal axis), together with the membranes which invest them—as also the nerves issuing from such parts, including those which are spoken of as the *sympathetic system.*

3. Here we must recapitulate so far as to state that the solid structures (skull and neural vertebral canal) which protect the cerebro-spinal axis are lined by a dense membrane— the *dura mater;* while the cerebro-spinal axis itself is closely invested by a delicate membrane—the *pia mater.* Interposed between the two is a double very delicate epithelial layer (called the *arachnoid*), forming a shut sac (as the peritoneum forms a shut sac) and containing the *arachnoid fluid.*

The cerebro-spinal axis encloses a cavity (of very different size and shape in different parts) which is lined by another very delicate epithelial layer called the *ependema.*

4. The BRAIN fills up the whole cranial cavity, fitting into all those depressions which we have found to exist on the floor of that cavity.

On removing the upper part of the skull and the *dura mater*, the surface of the brain is seen as a convex mass covered with numerous meandering, contorted prominences (*convolutions* or *gyri*), separated by corresponding depressions (*fissures* or *sulci*). The whole mass is sharply divided by a very deep fissure running from before backwards, and dividing the visible part of the brain into two lateral halves,

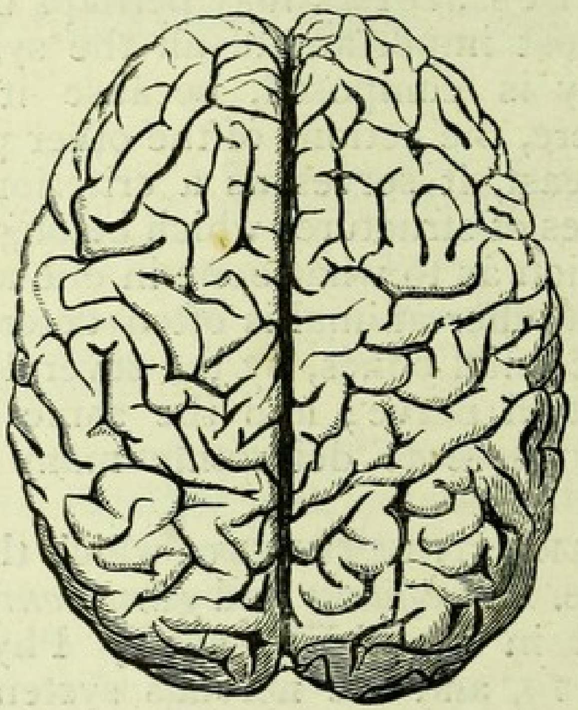

FIG. 323.—THE UPPER SURFACE OF THE BRAIN OF MAN, showing the deep longitudinal fissure dividing the two hemispheres, with their numerous and unsymmetrical convolutions.

termed *hemispheres*, and the whole convoluted mass is called the *cerebrum.* Thus the cerebral hemispheres of man extend so far forwards, outwards, and backwards that no other part of the cerebro-spinal axis is visible when the brain is viewed from above The *pia mater* so closely invests this mass that it passes down not only into the great median longitudinal fissure, but into all the sulci of the cerebrum. The *dura mater* passes into the longitudinal fissure only, where it forms the falx, which, as we have found in some animals (*e.g.* the Ornithorhynchus), becomes ossified.

Upon pushing apart the two cerebral hemispheres, these are seen to be connected by a large transverse band (called the *corpus callosum*) which extends much nearer to the anterior than to the posterior end of the longitudinal fissure. In front of the corpus callosum is seen nothing but the anterior fossa of the cranial cavity; but behind the corpus callosum (after removing that fold of the dura mater, the tentorium—so often ossified in brutes—which extends in from behind, below the cerebrum) we find the upper surface of another part of the cerebro-spinal axis, called the *cerebellum*, which is marked with numerous transverse, close, narrow grooves. To remove the entire brain from the skull it is necessary to cut through that part of the cerebro-spinal axis where the brain (at the foramen magnum) becomes continuous with the spinal marrow.

5. Having done this, and inverted the organ, a variety of parts come into view, its INFERIOR SURFACE being very irregular and complex as compared with its superior surface.

Proceeding from behind forwards, we find that the part in front of the section which we have just made is narrow and cylindrical. This is the *medulla oblongata*. It is marked by a median groove, on each side of which is what is called the *anterior pyramid*, and outside each such pyramid is a rounded, oblong prominence, termed the *olivary* body; and external to and behind each of these is a band named the *restiform* tract. The cut surface of the medulla exhibits that double-crescentic arrangement of grey tissue described in the "Elementary Physiology," Lesson XI. § 5.

On each side of the medulla oblongata is seen a large convex mass of tissue marked with many curved, transverse, narrow grooves. This is the cerebellum. and its two lateral parts meet together behind the medulla and form what is called the *inferior vermis*. This latter is the under part of that median portion of the cerebellum which we saw by divaricating the hinder parts of the cerebral hemispheres—and which is called the *superior vermis* (Fig. 328, *sv*). The median part of the cerebellum is small compared with its two great lateral lobes.

The cerebellum lies in that fossa of the cranial cavity which we have seen to be bounded in front by the petrous part of the temporal bones, and behind by the line of attachment of the tentorium to the occipital bone.

On each side of the anterior part of the under surface of the cerebellum is a small process, or lobe, called the *flocculus*. It does not occupy any special fossa in the temporal bone.

Continuing on in the middle line, we find in front of the medulla oblongata, a convex eminence formed of transverse fibres running across from one lateral lobe of the cerebellum

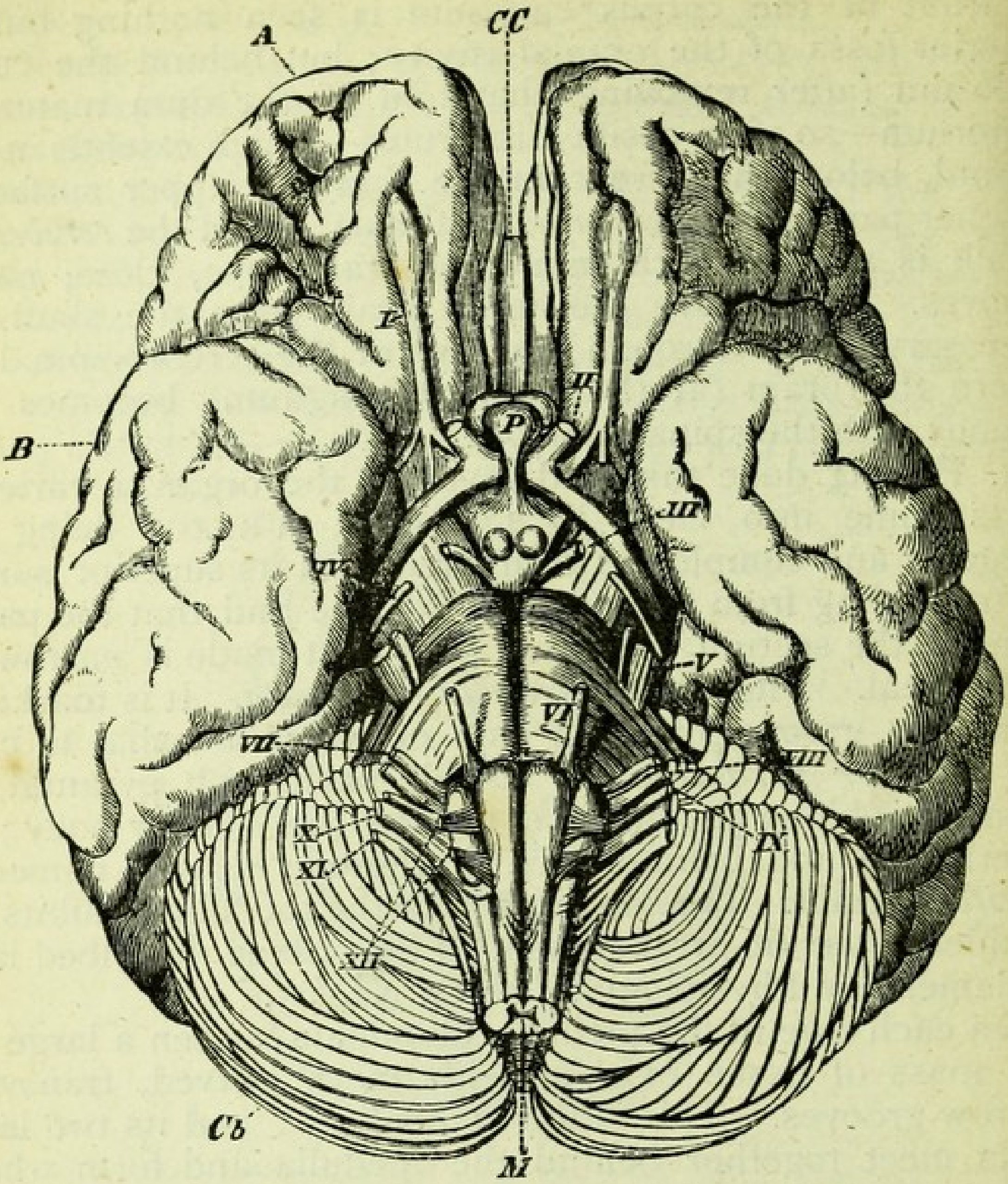

FIG. 324.—THE BASE OF THE BRAIN.

A, frontal lobe ; *B*, temporal lobe of the cerebral hemispheres ; *CC*, corpus callosum ; *Cb*, cerebellum ; *M*, medulla oblongata ; *P*, the pituitary body ; *I*. the olfactory nerve ; *II*. the optic nerve ; *III*. *IV*. *VI*. the nerves of the muscles of the eye ; *V*. the trigeminal nerve ; *VII*. the portio dura ; *VIII*. the auditory nerve ; *IX*. the glosso-pharyngeal ; *X*. the pneumogastric ; *XI*. the spinal accessory ; *XII*. the hypoglossal, or motor nerve of the tongue. The number *VI*. is placed upon the *pons Varolii*. The crura cerebri are the broad bundles of fibres which lie between the third and the fourth nerves on each side. Between the crura cerebri and behind the pituitary body are placed the rounded *corpora mammillaria*. *S*, sylvian fissure.

to the other, somewhat like a bridge, and thence called the *pons Varolii*. It lies upon the basilar surface of the occipital bone.

Emerging from the front of the *pons* are two masses of longitudinal fibres (called the *crura cerebri*) which diverge as they advance, and are crossed superficially by two anteriorly converging round cords, the *optic tracts* (which unite to form the optic nerves), and thus a lozenge-shaped space is enclosed. In the hinder part of this space are two small rounded bodies placed side by side, called the *corpora mammillaria*. In front of these is a slight prominence termed the *tuber cinereum*, from the middle of which projects a conical process, the *infundibulum*; at the end of the infundibulum is a small oval reddish mass called the *pituitary body*, which is received into the pituitary fossa (or sella turcica) of the sphenoid bone.

In front and beside these small median parts are those voluminous masses the cerebral hemispheres, which thus form the larger part of even the under surface of the brain.

The great longitudinal fissure is seen in the middle line in front, and another considerable lateral fissure (called the Sylvian fissure) separates obliquely (Fig. 325) the anterior (or *frontal*) lobe from the one behind (or *temporal* lobe) of the same hemisphere. This Sylvian fissure receives (when the brain is in place) the hinder edge of the orbital wing of the sphenoid, while the frontal lobe lies upon the orbital plate of the frontal bone, and the temporal lobe lies in that cranial fossa which is bounded in front by the orbital wing of the sphenoid and behind by the petrous part of the temporal bone.

In a groove on the under surface of each frontal lobe is a body, shaped something like a life-preserver, with an oblong head and a long stalk. This is the *olfactory* lobe, the so-called "olfactory nerve."

Upon turning back the optic tracts—at their union in what is called the *optic commissure*—a delicate layer is seen to connect them with the anterior end of the corpus callosum. This delicate layer is called the *lamina cinerea*, or *lamina terminalis*.

When the brain is viewed in profile we see the convoluted surface of one of the cerebral hemispheres with the deep Sylvian fissure running backwards and slightly upwards from its inferior margin, and separating the temporal lobe from the frontal one. When this fissure is opened out, a triangular convoluted prominence is exposed, called the *Island of Reil*. Below and behind the cerebrum we see the cerebellum with the pons Varolii in front of it, beneath which the medulla runs down to merge into the spinal cord (Fig. 325).

To obtain a more complete knowledge of the structure of the brain, certain definite sections must be made.

6. Thus, if the whole organ be VERTICALLY BISECTED in the line of the longitudinal fissure, we find as follows:—

The inner surface of the cerebral hemisphere in view is

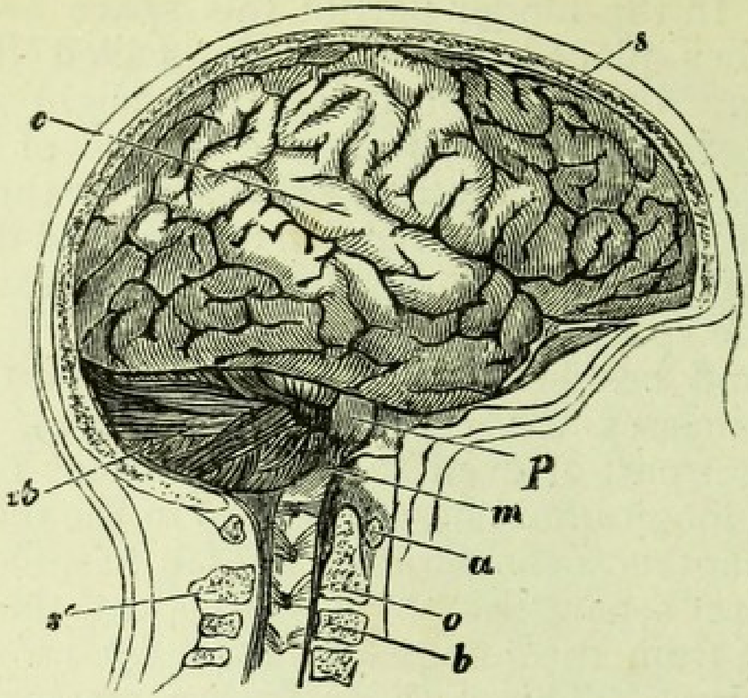

FIG. 325.—SIDE VIEW OF THE BRAIN AND UPPER PART OF THE SPINAL MARROW in place, the parts which cover the cerebro-spinal centres being removed.

a, front part of atlas vertebra applied to the odontoid process (*o*) behind it; *b*, body of third cervical vertebra; *c*, cerebrum—the long continuous groove immediately above the convolution to which the letter *c* points, is the *Sylvian fissure*, while the convolution itself forms part of the *temporal lobe* of the cerebrum; *cb*, cerebellum; *m*, medulla oblongata; *p*, pons Varolii; *s*, arch of skull cut through; *s'*, spinous process of axis vertebra.

very much convoluted, and the cerebrum may be seen to extend beyond the olfactory lobe in front and beyond the cerebellum behind.

Beneath the middle of the cerebrum we come to the cut surface of the corpus callosum, the front part of which bends sharply backwards and downwards, forming what is called the knee (*genu*). Beneath the bent-back extremity of the corpus callosum is the cut edge of the lamina cinerea (or terminalis). At the upper part of this lamina we find the cut surface of a transversely-extending white cord, called the *anterior commissure*, and immediately behind the lamina we find another cord, part of what is called the *fornix*. This latter structure extends, not transversely, but at first upwards and forwards, afterwards curving backwards it passes to the hinder part of the corpus callosum. Filling up the space between the corpus callosum and fornix is a delicate membrane called the *septum lucidum*.

Below the fornix we have evidently cut into a cavity extending down into the infundibulum and bounded in front by the lamina terminalis. This cavity is called the *thira*

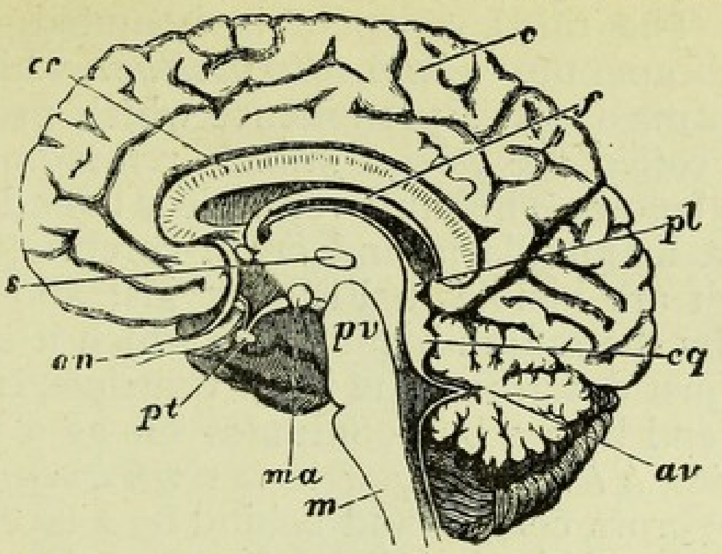

FIG. 326.—THE BRAIN AS SEEN WHEN A VERTICAL LONGITUDINAL SECTION HAS BEEN MADE THROUGH ITS MIDDLE.

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.

ventricle. A small aperture (the *foramen of Monro*) opens immediately behind the anterior part of the fornix, and a

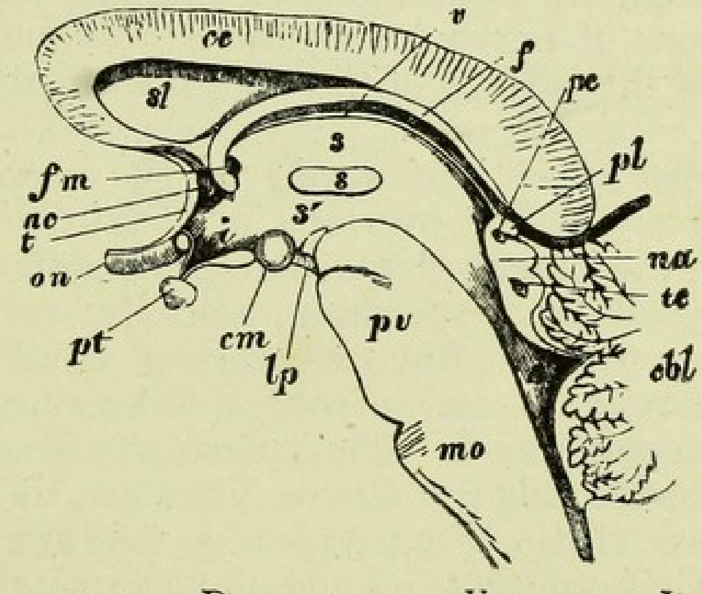

FIG. 327.—ENLARGED AND DIAGRAMMATIC VIEW OF A VERTICAL SECTION CARRIED THROUGH THE CORPUS CALLOSUM AND THE PARTS BELOW.

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 third ventricle ; 4, fourth ventricle—between them is the *iter a tertio ad quartum ventriculum*.

little behind this aperture is the cut edge of a bundle of transverse fibres which form what is called the *soft* (or *middle*) *commissure*. The third ventricle is bounded above by a delicate membrane, the *velum interpositum*, which thickens behind and forms a small prominence which projects backwards and is called the *pineal gland*—reminding us of the pituitary body below. The third ventricle is bounded inferiorly by the corpora mammillaria and crura cerebri (the cut surfaces of which are visible in Fig. 327 just above the pons Varolii), and by the infundibulum, into which it extends.

The cavity just described, the third ventricle, is not shut in at its hinder end below, but continues on as a very narrow passage (the *iter a tertio ad quartum ventriculum*), bounded in front by the crura cerebri and behind by a layer of nervous matter continuous with the pineal gland, and exhibiting the cut surface of a small transverse cord (the *posterior commissure*), and also two prominences in section—part of the *corpora quadrigemina*. A little lower down, this passage expands into a second cavity (the *fourth ventricle*), bounded in front by the medulla oblongata and behind by the cerebellum above, and below the cerebellum by an exceedingly delicate layer of nervous tissue.

The cerebellum in section shows singular radiating tree-like ramifications of nervous substance (grey and white), due to infoldings of the surface of the organ, and called the *arbor vitæ*.

Thus the extension backwards of the corpus callosum and cerebrum altogether overlaps a certain portion of the brain, namely, the pineal gland and parts adjacent. When these are exposed by a special section the corpora quadrigemina are seen to consist of two pairs of small prominences (but little different in size) placed side by side immediately behind the pineal gland. The anterior pair are called the *nates*, the posterior pair the *testes*. They are solid structures.

7. OTHER SECTIONS (Figs. 328 and 329) are necessary to make clear other matters. Thus, the *foramen of Monro* is the entrance to a cavity which is placed in the cerebral hemisphere of the same side, these two cavities constituting the first and second (or two *lateral*) ventricles.

The so-called foramen of Monro is, in fact, a Y-shaped passage. It is single below, where it communicates with the third ventricle, but divides above into two branches, one to each lateral ventricle.

Each lateral ventricle is tri-radiate and said to have three cornua. The *anterior cornu* passes into the frontal lobe. The *posterior cornu* passes into the hinder or occipital lobe. The third, or *descending cornu*, passes into the temporal lobe. Certain sulci on the surface of the cerebrum extend so deeply as to produce eminences on the inner surface of the lateral

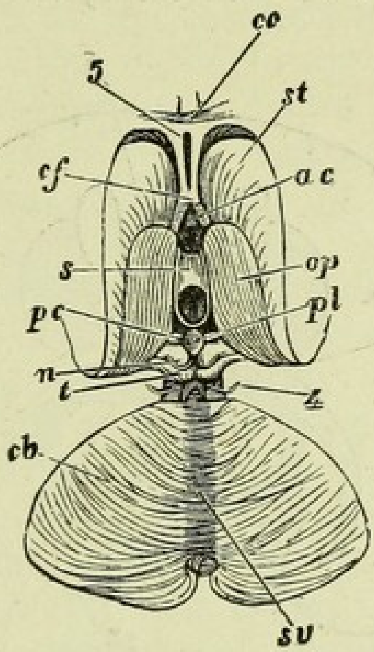

FIG 328.—HORIZONTAL SECTION OF PART OF THE BRAIN, the cerebrum and velum interpositum being removed, the fornix and septum lucidum being cut through, and the third and fifth ventricles and the upper surface of the cerebellum being exposed.

ac, anterior commissure; *cc*, corpus callosum; *cb*, cerebellum; *cf*, crura of fornix; *n*, nates; *op*, optic thalamus; *pc*, posterior commissure; *pl*, pineal gland; *s*, middle, or soft commissure; *st*, corpus striatum; *sv*, superior vermis; *t*, testes; 4, fourth nerve; 5, fifth ventricle—on each side of it is a lamina of the septum lucidum cut through.

ventricles. One such insignificant structure in the posterior cornu is spoken of as the *hippocampus minor;* another in the descending cornu has been termed the *hippocampus major*.

Careful inspection shows that the septum lucidum is really double, enclosing a very narrow space—the *fifth ventricle*—the laminæ of the septum lucidum passing downwards from the corpus callosum to the fornix.

This fornix is made up of two white cords closely approximated anteriorly and diverging widely behind. Each springs from one of the corpora mammillaria, and the two cords (crura) ascend (side by side) behind the anterior commissure, and with a branch of the foramen of Monro on the outer side of each. They then curve backwards, diverging, but at the same time united by a delicate membrane called the *lyra*. They become connected with the corpus callosum, and then pass into each descending cornu of the lateral ventricles.

Two rounded bodies (the *optic thalami*) are placed one on each side of the first described cavity (the *third ventricle*), and are connected by the soft and posterior commissures. Two other rounded bodies (the *corpora striata*) are placed one in each cerebral hemisphere between the anterior and descending cornua. They are connected by the anterior commissure.

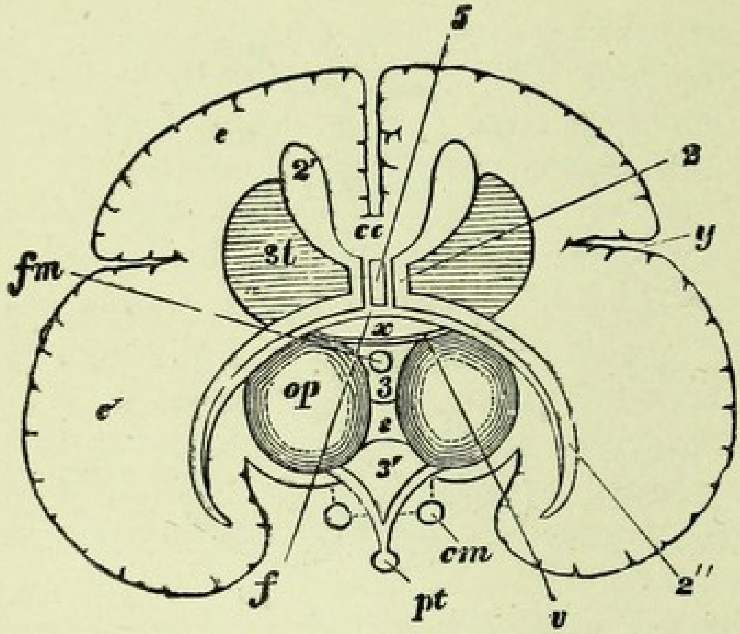

FIG. 329.—DIAGRAM OF A TRANSVERSE VERTICAL SECTION OF THE BRAIN, MADE THROUGH THE SECOND, THIRD, AND FIFTH VENTRICLES.

c, cerebrum ; *c'*, its temporal lobe ; *cc*, corpus callosum ; *cm*, corpora mammillaria; *f*, fornix ; *fm*, foramen of Monro ; *op*, one of the two optic thalami ; *pt*, the pituitary body ; *s*, middle, or soft commissure ; *st*, one of the two corpora striata ; *v*, velum interpositum ; *x*, space enclosed between the velum and the fornix ; *y*, fissure of Sylvius ; 2, lateral ventricles ; 2', the ascending cornu of a lateral ventricle; 2'', its descending cornu ; 3 and 3', the third ventricle ; 5, the fifth ventricle.

8. The DEVELOPMENT of this complex organ is as follows :—At first there are three hollow vesicles placed one in front of the other, their three cavities (which open one into another) being expansions of the anterior end of the primitive groove and subsequent canal of the embryonic cerebro-spinal axis. These three vesicles are called respectively, (1) the hind-brain, (2) the mid-brain, and (3) the fore-brain (Fig. 330).

The superior surface of the fore-brain becomes the velum interpositum, and from its hinder part the pineal gland arises, while the infundibulum and pituitary body appear at its inferior surface. Its cavity is therefore what afterwards becomes the third ventricle.

The mid-brain becomes the corpora quadrigemina above and the crura cerebri below, while its greatly reduced cavity is ultimately the iter a tertio ad quartum ventriculum.

The hind-brain sends out an outgrowth above, which is the cerebellum. Its upper wall becomes excessively thin, a mere delicate layer of epithelium, which roofs its cavity—the fourth ventricle.

The anterior end of the first vesicle (or fore-brain) becomes the lamina terminalis. On each side of it another vesicle grows out, which is one of the cerebral hemispheres, and the aperture of communication is the future foramen of Munro.

From the anterior part of the floor of each cerebral hemisphere yet another vesicle buds forth, which is the future olfactory lobe (or nerve), the cavity of which becomes obliterated in the adult.

The three original hollow vesicles and the olfactory lobes remain small, but the cerebral hemispheres grow out of all proportion to the other parts. They also become united together by an outgrowth of transverse connecting fibres (the corpus callosum), which outgrowth, by this mode of development, comes to enclose what was originally the deepest part of the great longitudinal fissure. The space thus enclosed is, of course, bounded on each side by part of the inner wall of one of the cerebral hemispheres. These parts of the inner cerebral walls become however excessively thin, and the two parts together form the septum lucidum, while the space enclosed between them becomes the fifth ventricle. Thus the fifth ventricle is quite different in its nature from all the other ventricles of the brain, it being taken in as it were from outside space, while all the others are either remnants of the primitive embryonic dorsal groove and canal, or (as the lateral and primitive olfactory ventricles) outgrowths from and extensions of such.

9. We may now better understand the nature of some of the parts before noticed.

The *fornix* is the median part of what was originally the back of the hemispheres. It (together with the lyra which joins the two diverging and posterior portions of the fornix), really forms part of the outer wall or bag of the cerebrum, enclosing the lateral ventricles—each half of the fornix belonging to one of the hemispheres. As these grow backwards, the fornix looks more and more downwards, following the course of the developing "temporal lobe."

Beneath the fornix is the roof of the third ventricle, *i.e.* the velum interpositum, and the space between the upper surface of this velum and the under surface of the closely applied lyra is morphologically the *outside* of the brain, though in fact it is in the middle of the complex whole of the adult structures.

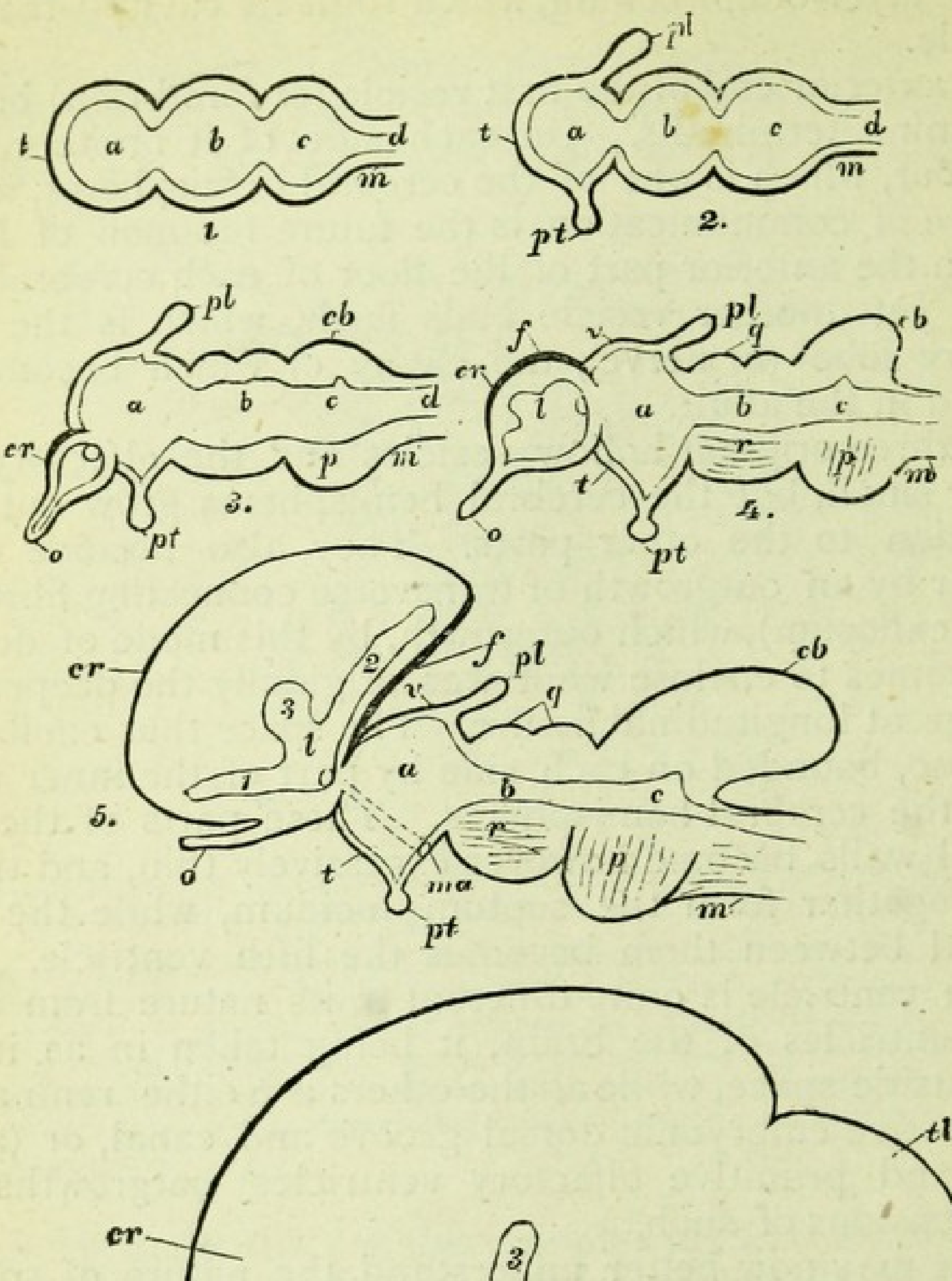

FIG. 330.—DIAGRAM ILLUSTRATING THE PROGRESSIVE CHANGES THAT TAKE PLACE DURING SUCCESSIVE STAGES OF THE DEVELOPMENT OF THE BRAIN.

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 vesicles 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 tri-radiate 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, as in Fig. 325. 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 cerebrum; *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.

The *velum* consists only of the ependyma, the pia mater, and the arachnoid. Its margins are very vascular, and bear the name of the *choroid plexuses*. The vascularity continues in that part of the ependyma which passes through the foramen of Munro into the lateral ventricles, but of course the pia mater and arachnoid do not pass through that foramen, as they never get inside the ventricles at all, but are reflected back on the under surface of the fornix. Thus the "choroid plexuses" of the lateral ventricles are (like those of the third) merely portions of the ependyma, which happen to be very vascular, and not intrusions from without.

Each *cerebral hemisphere* is a bag with walls of very unequal thickness. Thus, part of the inner wall running along the descending cornu of the lateral ventricle is reduced to the ependyma (with the pia mater and arachnoid), and readily tears (forming the fissure of Bichat), and this rupture having been mistaken for a natural opening, each lateral ventricle has been supposed to communicate with the exterior close to the crus cerebri. Each corpus striatum is an outgrowth from the middle of the base of its hemisphere, and forms the axis around which the whole hemisphere is developed. The "Island of Reil" lies in the outer surface of each corpus striatum.

The *optic thalami* are thickenings in the outer walls of the third ventricle.

The *corpora mammillaria* are the anterior inferior ends of the fornix, being the roots of what are called its "anterior pillars."

The roof of the fourth ventricle is formed of the ependyma alone, the pia mater and arachnoid being reflected over the postero-inferior surface of the cerebellum.

The "temporal lobe" of the cerebrum is developed early; the "occipital lobe" is a subsequent outgrowth from the hinder part of the hemisphere.

At first the cerebral hemispheres are smooth, the various convolutions arising successively as development proceeds.

The corpora quadrigemina are at first represented by but a single hollow prominence on each side.

10. A survey of the brain of Vertebrates generally, shows us that this organ in man attains a very notable degree of SIZE and complexity. Yet the convolutions of the cerebrum may be still more numerous than in him, as we see in the Whales; and the absolute size of the organ in the same animals exceeds that of man very considerably.

It might be supposed that the mass of the brain in man, as compared with the weight of his body, is at a maximum; but it is not so, for even in some small Birds the proportional weight of the brain is more than twice as great as in man.

Nevertheless, considering man's actual bulk, the relative size of his brain is very large, for, speaking generally, the larger the body the less the relative size of the brain; so that we may safely assert that no animal *with his bulk of body* has a brain nearly so large relatively as man has.

11. The CEREBRAL HEMISPHERES in man, in that they are excessively convoluted, agree with those of the largest animals of man's own class, but in the smaller members of even his own order (*e.g.* some American Monkeys) they may be almost smooth, as is the case in all below Mammals. They may be broader relatively than in man, as in Cetaceans, and in a less degree in Seals. They may be more truncated anteriorly (as in Ruminants), or more pointed (as in the Rabbit).

They may, by rare exception, project back beyond the cerebellum more than in man, as in the Saimiri, or they may fail to cover that organ even in an Anthropoid Ape, *i.e.* in the Siamang Gibbon. Generally it is widely uncovered, and even in Mammals (*e.g.* in the Insectivorous Bats) the cerebrum may leave the pineal gland and corpora quadrigemina uncovered also, as generally is the case in forms below Mammals.

The presence of lateral ventricles is characteristic of all Vertebrates above Fishes, though the possession of *tri-radiate* lateral ventricles is a character almost peculiar to Man and Apes—as only in the Seals besides is there a small posterior cornu. Thus the posterior cornu appears, late in zoological order as in chronological order, in man himself. Next to the occipital lobe, the temporal one dwindles as we proceed from man, the Sylvian fissure gradually opening outwards till (as *e.g.* in the Rabbit) there is but a faint indication of it. The cerebral hemispheres may be solid, as in Teleostean Fishes, *e.g.* the Perch.

That transverse commissure, the corpus callosum, may be wanting, as in all below Mammals, and where it is absent no fifth ventricle is, of course, enclosed. *Pari passu* with the diminution of the corpus callosum we find generally in man's class an increase in the relative size of the anterior commissure, but below man's class the latter remains small in spite of the absence of the former. Sometimes, however (as in Cetacea), with only a fairly developed corpus callosum, the anterior commissure may be almost obsolete.

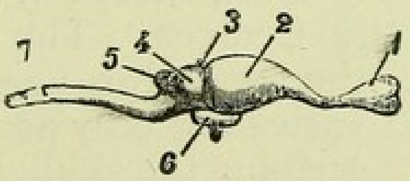

FIG. 331.—RIGHT SIDE VIEW OF BRAIN OF THE COMMON LIZARD (*Lacerta agilis*).

1, olfactory lobe ; 2, cerebral hemispheres ; 3, pineal gland ; 4, one of the optic lobes ; 5, cerebellum ; 6, pituitary body ; 7, spinal marrow.

12. The OLFACTORY LOBES of man are mere rudimentary structures compared with their condition in many animals, as *e.g.* in the Rabbit, and very often the ventricular cavity which is but transitorily present in man, is permanent. They may be sessile prominences, close to the hemispheres, as in the Eels, or placed at the end of large diverging peduncles, as in the Rays (Fig. 336, 1). They may considerably exceed the cerebral hemispheres in size, as in the Lamprey.

The *true* OLFACTORY NERVES are filaments which pass from the lobes to the inner surface of the olfactory organ. In man and Mammals they pass through the foramina of the cribriform plate to the mucous membrane, investing the spongy bones (or lateral ethmoid and turbinals) as described in Lesson VIII. § 13 of the "Elementary Physiology."

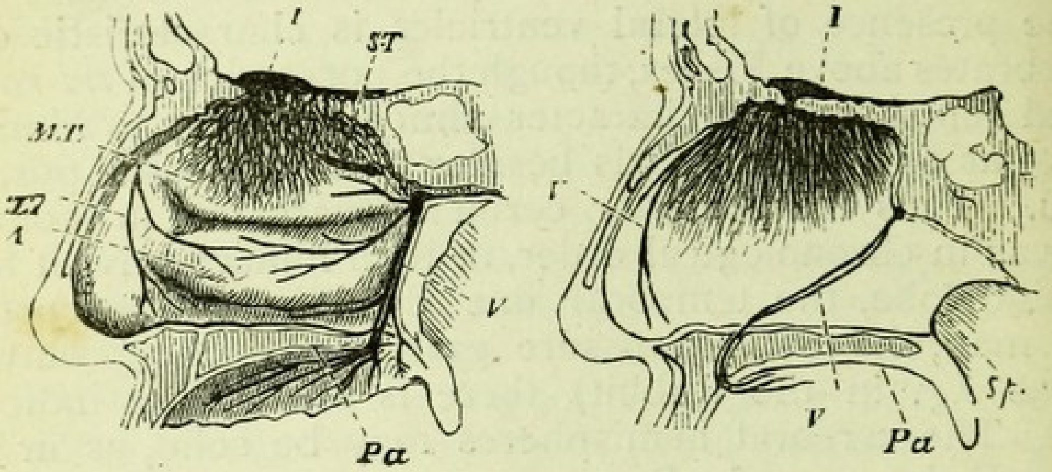

FIG. 332.—VERTICAL LONGITUDINAL SECTIONS OF THE NASAL CAVITY.

The left-hand figure represents the outer wall of the right nasal cavity; the right-hand figure the left side of the middle partition or septum of the nose, which forms the right wall of the left nasal cavity.

I, the olfactory lobe and its branches; *V*, branches of the fifth nerve; *Pa*, the palate which separates the nasal cavity from that of the mouth; *ST*, the superior turbinal bone; *MT*, the middle turbinal; *IT*, the inferior turbinal. The letter *I* is placed in the cerebral cavity. The partition on which the olfactory lobe rests, and through which the filaments of the olfactory nerves pass, is the cribriform plate.

An essentially similar arrangement to that in man exists in all Vertebrates above Fishes, except in those destitute of an olfactory organ, as the Cetacea. The place of opening of the posterior nares within the mouth varies not only as before noticed in describing the skull, but the aperture may be placed half-way down the throat, as in *Myrmecophaga*. The singular elongation of the nose in the Elephant has also been adverted to in the Lesson on the Muscles. Singular leaf-like expansions of membrane may be developed from the external skin of the nose, as in the Horse-shoe Bats (*Rhinolophus* and *Megaderma*, especially the latter genus) and Vampires (*Phyllostoma*); and an extra median ossicle may be developed in the snout, as *e.g.* in the Mole.

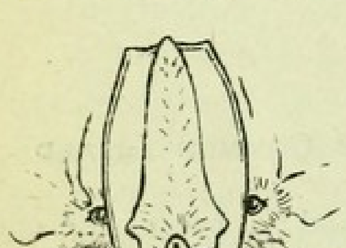

FIG. 333.—MEMBRANE DEVELOPED ON THE NOSE OF THE BAT *Megaderma lyra*.

The anterior bony nares may be continued on by a single passage having a single opening on the surface (as in the Porpoise), the channel being also connected with a complex appendage of sacs.

Each nostril may still have two apertures, and yet both of these may open on the external surface, as in Fishes. Finally, the nasal organ may be absolutely single and median, as in the Marsipobranchs, ending below in a blind termination, as in the Lamprey, or opening into the pharynx, as in the Myxine.

13. The envelope of the THIRD VENTRICLE of the brain is a most constant and morphologically important structure, small and subordinate as it appears in adult man. We have seen, however, that the fore-brain is relatively large at first, even in him, and it so remains in all the members of the lowest class of Vertebrates.

In Fishes indeed this part attains a great relative size, and by some anatomists it is believed to combine with part of

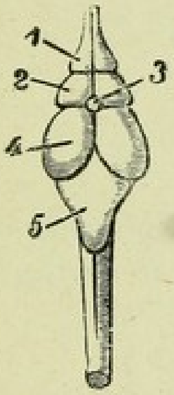

FIG. 334.—BRAIN OF THE PERCH (*Perca fluviatilis*) SEEN FROM ABOVE.

1, one of the olfactory lobes; 2, one of the cerebral hemispheres; 3, the pineal gland; 4, one of the hollow vesicles commonly called "optic lobes"; 5, the posterior median prominence commonly termed the cerebellum, but by some deemed to be a special development of the "mid-brain."

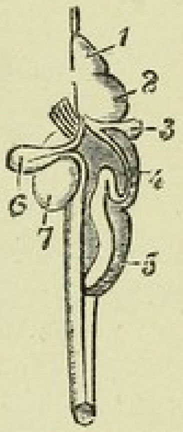

FIG. 335.—VERTICAL LONGITUDINAL SECTION OF THE BRAIN OF THE PERCH.

1, an olfactory lobe; 2, one of the cerebral hemispheres; 3, pineal gland; 4, the so-called "optic lobes," showing the large cavity they contain; 5, the median structure commonly termed the cerebellum; 6, the pituitary body; 7, one of the *lobi inferiores*.

the mid-brain to form a large pair of hollow vesicles in proximity to the cerebral hemispheres, and to have various complexities of structure within its cavity. This segment of the brain is well marked out by the pineal gland above and the pituitary body below.

The *corpora mammillaria* may be single, as in the Rabbit, or absent, as in Sauropsida. A pair of inferior prominences may exist below this region of the third ventricle, called *lobi inferiores* (Fig. 335, 7), which may, but more probably do not, answer to the corpora mammillaria.

14. The *corpora quadrigemina* in man are again but feeble rudiments compared with their possible relative development as shown by the brains of other animals. The nates may be smaller than the testes (as in the Hedgehog), or larger (as in the Rabbit). In that this mid-brain region in man bears these four prominences, it agrees with the same part in all Mammals, but among Sauropsidans we find instead, two large rounded hollow spheres (called the optic lobes), placed in Reptiles immediately behind the hemispheres, but in Birds depressed to the side of the brain, below the level of the cerebellum (Fig. 338, 4).

It is, however, in Fishes that the mid-brain region attains its maximum relative size. This region is considered by most writers to form the optic lobes, but it has been asserted

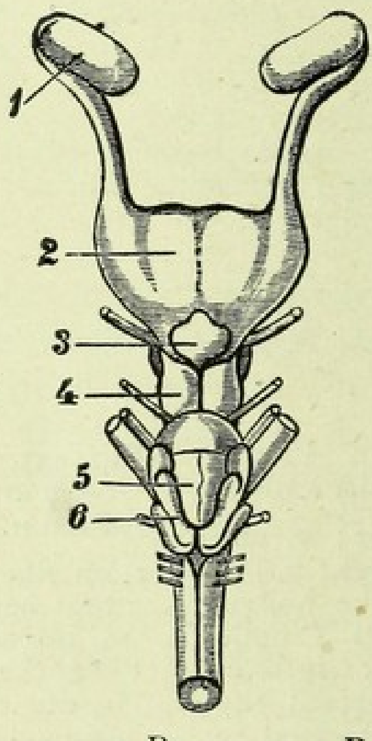

FIG. 336.—DORSAL ASPECT OF THE BRAIN OF A RAY OR SKATE (*Raia batis*).

1, one of the two olfactory lobes; 2, the conjoined cerebral hemispheres; 3, the pineal gland; 4, one of the so-called "optic lobes"; 5, the median structure commonly called the "cerebellum"; 6, one of the corpora restiformia.

to be yet more developed, and to include a part which has generally been regarded (and in all probability rightly so) as representing the cerebellum of higher animals. Thus in the Rays there is a great complex mass folded in numerous convolutions (commonly reckoned as the cerebellum) and extending in part into the cavity of the segment of the brain in front of it. In many Teleostei (*e.g.* the Conger) the corresponding structure may consist partly of a fold extending into the cavity of the more anteriorly situate cranial vesicle, partly of a great smooth median prominence behind it.

15. The CEREBELLUM of man, like his cerebrum, greatly exceeds the normal development of the part in Vertebrates generally, thus differing from the intermediate brain segments which, as we have seen, are in him below the average relative development of the same parts in Vertebrates.

As we descend from man we find an increase of the median portion of the cerebellum (the vermis) with a decrease of its lateral lobes, while the flocculus on each side becomes prominent, and is (as we have seen) received in a special fossa on the surface of the petrous bone.

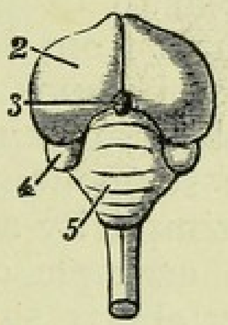

FIG. 337.—DORSAL ASPECT OF BRAIN OF A PIGEON (*Columba livia*).
2, one of the cerebral hemispheres; 3, pineal gland; 4, one of the optic lobes (here lateral and depressed); 5, cerebellum.

Complex folds, forming an *arbor vitæ*, are common to man's class, to Birds, and to the Crocodiles, but are wanting in lower forms.

The cerebellum, even in the highest Ichthyopsida—the Frogs and Toads—is reduced to little more than a transverse band; and it may be that it is hardly larger in Fishes, if, as has been asserted, it forms but the lower part of that great convex mass which has been usually described as the cerebellum, and which in the Elasmobranchs is so large and convoluted, and is large but smooth in the Teleostei. If, however, as is most probably the case, the convex mass *is* the cerebellum, then this organ, after dwindling in size in Batrachians, once more regains its importance as we descend to the lowest forms.

Transverse fibres connecting the two lobes of the cerebellum on the ventral side of the medulla are wanting in Birds, and in all below. In other words, a pons Varolii is a structure peculiar to man's own class.

16. The MEDULLA OBLONGATA of man is normal, but less complex than in much lower forms.

Even in some members of man's own order (*e.g.* the American Apes) certain additional structures (called *corpora trapezoidea*) separate the upper ends of the pyramids from the pons Varolii.

The side walls of the fourth ventricle may be remarkably contorted (as in Rays), forming what is called *corpora restiformia* (Fig. 336, 6).

The little extension backward, or the rudimentary condition of the cerebellum, sometimes causes the fourth ventricle to come plainly into view, as we see in the Frog and the Lamprey. The fourth ventricle may be relatively enormous, as in *Hexanchus*.

17. Thus it seems that man exaggerates those characters which distinguish Mammals from lower Vertebrates; *i.e.* in him the cerebrum and cerebellum are advanced to a maximum of relative size and complexity, while the parts which represent those primitive segments, the fore-brain and mid-brain, show an extreme simplicity and relative inferiority of size. Man's brain is an example of one of three types of structure found in the Vertebrate sub-kingdom.

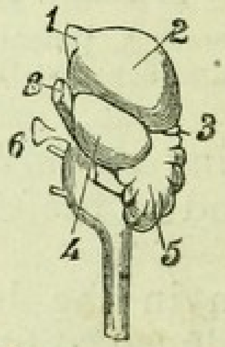

FIG. 338.—LEFT SIDE VIEW OF BRAIN OF PIGEON (*Columba livia.*)

1, olfactory lobe; 2, cerebral hemispheres: 3, pineal gland; 4, one of the optic lobes (here lateral and depressed); 5, cerebellum; 6, pituitary body; 8, optic nerve.

The two other types are (1) the Sauropsidan brain and (2) the Piscine brain. In the first we meet with hollow hemispheres, large optic lobes (superior, or lateral and depressed), no lobi inferiores, no enlarged roof to the third ventricle, and no fold of brain-substance extending into a cavity beneath the so-called optic lobes, while often a well-developed cerebellum exhibits the arbor vitæ. In the second type we meet with solid hemispheres, often with lobi inferiores (Fig. 335, 7), an enlarged roof to the third ventricle, and a pair of large hollow optic lobes, often with a fold of brain-substance running forward into their cavity, while what is commonly reckoned as the cerebellum is more or less developed, but without an arbor vitæ.

In the lowest forms we find instead of, as in man, a series of segments enclosed by an enormous expansion of what were primitively terminal bodies, merely a number of segments plainly arranged in a linear series and undisguised by the excessive development of any one constituent part.

18. The SPINAL MARROW in man has been described in the "Elementary Physiology" (Lesson XI. § 4)—how the cylindrical nervous mass is divided by two vertical median fissures

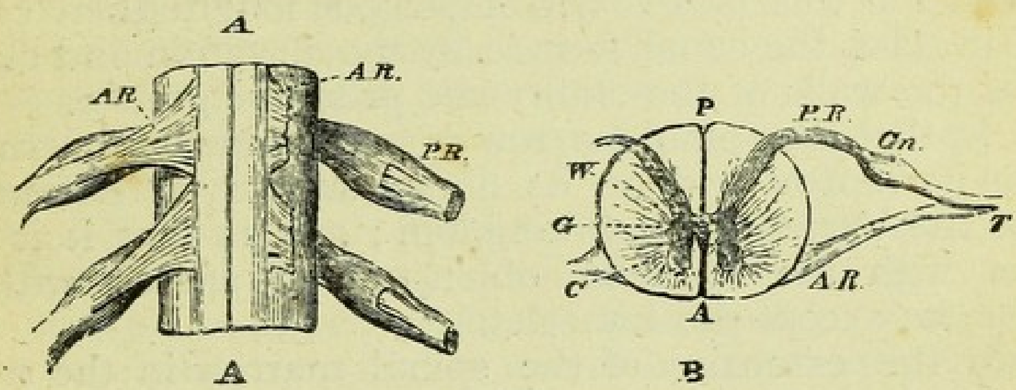

FIG. 339.—THE SPINAL CORD.

A, Front View of a portion of the Cord. On the right side, the anterior roots of spinal nerves, *AR*, are entire; on the left side they are cut, to show the posterior roots, *PR*.
B, A Transverse Section of the Cord: *A*, the anterior fissure; *P*, the posterior fissure; *G*, the central canal; *C*, the grey matter; *W*, the white matter; *AR*, the anterior root; *PR*, the posterior root; *Gn*, the ganglion; and *T*, the trunk, of a spinal nerve.

(one before and the other behind) into two lateral halves, each of which is again subdivided by the two vertical series of spinal nerve-roots (one series being made up of the anterior roots, the other of the posterior ones) into three subordinate and less-defined vertical segments.

The spinal marrow extends (Fig. 351) from the foramen magnum nearly to the second lumbar vertebra, being continuous above with the medulla oblongata, and so occupies about the upper two-thirds of the neural canal. Below this region the canal is occupied by a bundle formed of the elongated roots of those spinal nerves which pass out at the lower lumbar and sacral foramina: this bundle is called the *cauda equina*. In the earlier stages of existence there is no such bundle, the spinal marrow then occupying the whole length of the neural canal. A relic of this early condition is seen in what is called the *nervus impar* or *central ligament*, which is a delicate filament passing down in the middle of the cauda equina to the bottom of the sacrum or to the coccyx. It is composed almost entirely of the pia mater which originally enveloped the primitively co-extended spinal marrow.

Two enlargements are found in the spinal marrow : one (called the cervical) at about from the third cervical vertebra to the first dorsal ; the other (called the lumbar) at about the last lumbar vertebræ. These do not exist at first : they are related to the nerves of the limbs.

A minute modification of tissue, the *canalis centralis*, continues on downwards, from the fourth ventricle of the brain, along the middle of the spinal marrow. In the earliest stages of life this is a very conspicuous longitudinal cavity, being in fact the canal formed by the elevation and closing over of the walls of the embryonic primitive groove.

19. In that the spinal marrow of man is medianly grooved both on its ventral and on its dorsal surface, it follows the rule of the Vertebrate sub-kingdom ; and in that it is continuous with the medulla oblongata, it agrees with all Vertebrates except the Lancelet.

As to the extension of the spinal marrow in the neural canal, man's embryonic condition agrees with that which is permanent in lower forms such as Fishes. In that very class, however, *e.g.* in *Diodon*, the spinal marrow may be much more shortened, and the *cauda equina* very much longer relatively than in man, while in his own class (as *e.g.* in the Hedgehog) these characters may be more marked than they are in him, and a conspicuous *cauda equina* is found in Frogs and Tortoises.

The posterior end of the spinal marrow may present a slight enlargement, as *e.g.* in the Cod.

The *canalis centralis* is much more conspicuous in lower forms, and in them persists plainly throughout life as a distinct longitudinal cavity. A singular enlargement of this canal may take place towards the lower end of the spinal marrow, as in Birds, where a sort of inferior repetition of the fourth ventricle (called the *sinus rhomboidalis*) exists in the situation of the lumbar spinal enlargement.

The cervical enlargement may alone exist, as in Cetaceans ; while, on the contrary, the cervical and lumbar enlargements may be both so far more marked than in man that the intervening part of the spinal marrow is reduced to a very slender condition, as is the case in the Tortoises.

20. The two cords which have been spoken of as the *optic tracts* arise, one on each side, from the optic thalami, and run forwards obliquely across the under surface of the brain, to join together immediately in front of the infundibulum, whence they again diverge as the OPTIC NERVES. At the point of junction the two tracts partially exchange their fibres as follows :—The outer fibres of each tract continue on to the optic nerve and eye of the same side. The inner fibres cross over to the optic nerve and eye of the opposite side. This decussation of fibres is called the optic commissure or *chiasma*. Beyond the chiasma each optic nerve passes through the corresponding optic foramen, invested in a sheath of the dura mater, and surrounded by the recti muscles. After piercing the outer coats of the eyeball, it expands within that globe into what is called the *retina*.

Posteriorly the optic nerves become connected with the corpora quadrigemina, or optic lobes, but this connexion does not exist at first.

The structure of the EYE has been so amply described in the Ninth Lesson of the "Elementary Physiology" that here it is only necessary to notice its development and its more important relations with the conditions presented by the eye in Vertebrates generally.

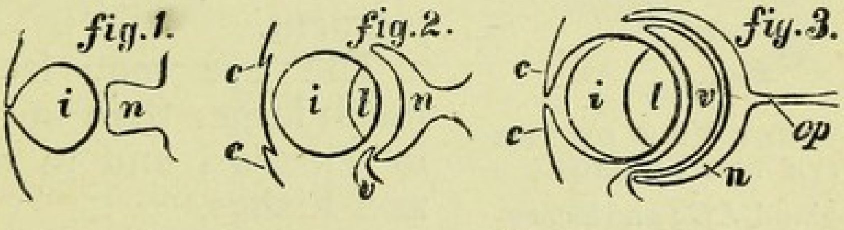

FIG. 340.—DIAGRAM REPRESENTING THE DEVELOPMENT OF THE EYE IN SUCCESSIVE STAGES, FROM FIG. 1 TO FIG. 3.

n, outgrowth from fore-brain becoming cup-shaped, applied to the back of the vitreous humour and forming the *retina*; *i*, the involution of the integument becoming posteriorly the *lens* (*l*) and anteriorly the *aqueous* humour; *v*, the lateral ingrowth which intrudes between the lens and nervous outgrowth and becomes the *vitreous* humour; *op*, the optic nerve; *cc*, the incipient skin-folds which become the *eyelids*; they are connected by the *conjunctiva*.

The eye is formed by the junction of an outgrowth from the brain with an ingrowth from the skin.

The outgrowth is from the fore-brain, and is in the form of a hollow process containing a prolongation of the primitive ventricular cavity.

This process becomes cup-shaped, and embraces the back of the part formed by the ingrowth of the skin.

The ingrowth becomes pinched off, its hinder part forming the *crystalline lens*, its anterior part the aqueous humour.

A third process intrudes inwards from one side, between these two growths, and forms the vitreous humour.

The connective tissue around the whole structure becomes condensed, as the sclerotic.

The external skin develops folds which increase and become the eyelids, and these are lined by a membrane reflected over the eyeball and called the *conjunctiva*.

At first the optic nerves are separated, not forming a chiasma.

At the outer angle of the orbit is the lachrymal (or tear-secreting) gland, the tears passing down a canal which traverses the lachrymal bone—as before noticed—into the nares.

In the possession of eyes man agrees with the immense majority of his sub-kingdom; nevertheless, these parts may be quite rudimentary and covered by the external hairy skin, as in the Mole. They may even, as in Myxine, merely consist of a minute lens in contact with the end of the optic nerve, which is coated with pigment.

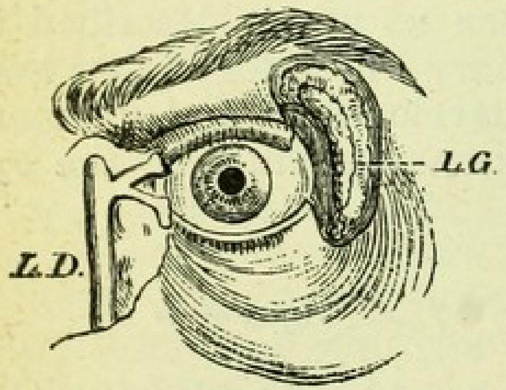

FIG. 341.—FRONT VIEW OF THE EYE, WITH THE EYELIDS.
Lachrymal gland, *LG*; and lachrymal duct, *LD*.

The eye may be relatively much larger than in man, as *e.g.* in *Tarsius*, and in many Birds and Fishes.

The sclerotic may be more or less ossified, as in Birds, Lizards, and many Fishes, but it is never so in man's own class.

The orbital muscles have been already described.

Part of the lateral process, which forms the vitreous humour, may persist in part in its more primitive condition as a distinct vascular membrane, covered with pigment, extending from near the entrance of the optic nerve to the lens. Such is the case in Birds and many lower forms, where it is called the *pecten*, or sometimes the *marsupium*.

Lachrymal glands may be entirely absent, as *e.g.* in aquatic forms—Fishes and Cetaceans.

Eyelids may be absolutely wanting, as in most osseous Fishes; or they may be apparently so, as in Serpents, where they really exist in a transparent condition and quite without division (into upper and lower), so that the primitive folds have, as it were, coalesced, entirely shutting off the conjunctival chamber from the exterior, except by means of the communication effected with the nares through the lachrymal canal.

A third eyelid (called the nictilating membrane) often exists, as *e.g.* in Birds, attached to the inner side of the front of the orbit. It is moved in various ways, as already noted in describing the muscles of the eye. A minute rudiment of this structure exists in man.

The form of the eyeball may be much less spherical than in man. Thus it may be much flattened anteriorly, as in Fishes; or, on the contrary, much elongated, *i.e.* anteriorly produced, as in Birds, *e.g.* the Owls.

The optic nerves may, after development, entirely or all but entirely abort, as in the Mole; but this atrophy is very exceptional.

On the other hand, that primitive condition of the optic nerves in which the fibres do not decussate may persist throughout life, as in the osseous Fishes; nevertheless, the nerves themselves cross (each one going to the eye of the side of the head opposite to that of its own origin), though they do not form a chiasma.

Unlike the nasal organ, the optic structure is never single and median except by monstrosity.

There may even be the appearance of two superimposed eyes on each side of the head. This remarkable structure occurs in the Fish *Anableps*, and is produced by the presence of a horizontal opaque tract in the middle of the cornea together with a double perforation of the iris.

FIG. 342.—RIGHT SIDE OF THE HEAD OF ONE OF THE PLEURONECTIDÆ.

Both eyes may come in the adult to be placed on one side of the head, as in the Flat Fishes, such as the Sole and Turbot; or both eyes may be closely approximated on the upper surface of the head, as in the Fish thence termed the Star-gazer (*Uranoscopus*).

Finally, each eyeball may be supported at the end of a long outwardly projecting pedicle, as in the Shark which on this account is called "Hammer-headed."

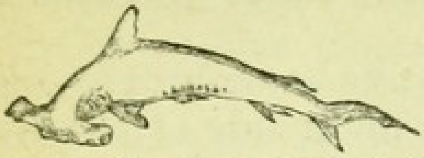

FIG. 343.—HAMMER-HEADED SHARK.

21. The so-called *olfactory* and *optic* nerves are thus not really *nerves*, but prolongations and outgrowths of the very brain itself; the other so-called cranial nerves (except a part of one, which part goes to the internal ear) are properly thus designated.

The THIRD AND FOURTH NERVES (Fig. 324) arise from the mid-brain, and go respectively—the first to all the orbital muscles except the upper oblique and the outer rectus; the second, to the upper oblique orbital muscle. Both these nerves traverse the spheno-orbital fissure.

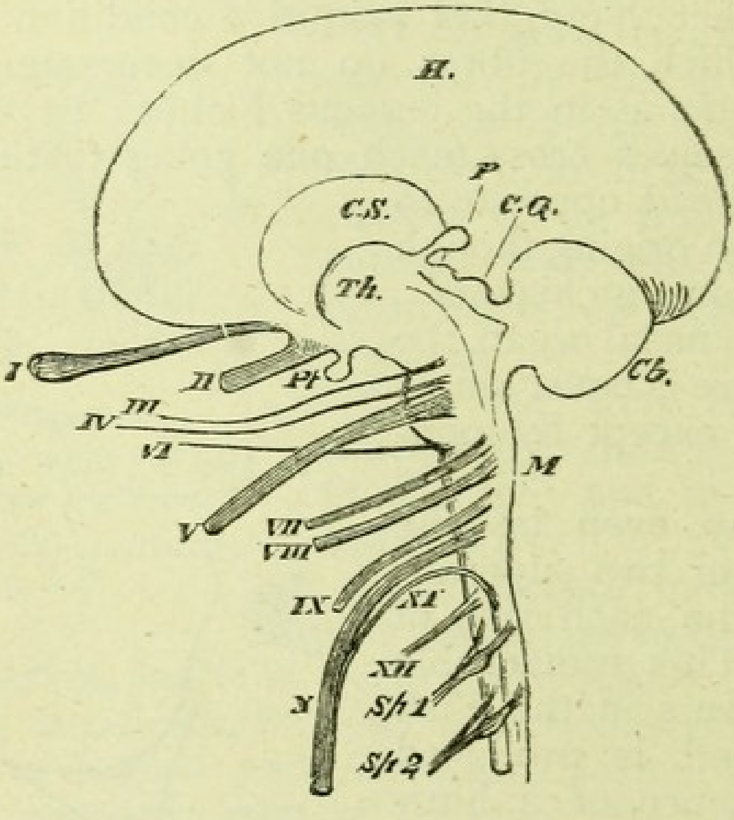

FIG 344.—DIAGRAM ILLUSTRATING THE ARRANGEMENT OF THE PARTS OF THE BRAIN AND THE ORIGIN OF THE NERVES.

H, the cerebral hemispheres; *CS*, corpus striatum; *Th*, optic thalamus; *P*, pineal gland; *Pt*, pituitary body; *CQ*, corpora quadrigemina; *Cb*, cerebellum; *M*, medulla oblongata; *I.—XII.*, the pairs of cerebral nerves; *Sp* [1] and *Sp* [2], the first and second pairs of spinal nerves.

The SIXTH NERVE arises from the base of the brain just in front of the medulla oblongata, and goes through the same fissure to the outer rectus muscle of the orbit.

These three nerves present a singular constancy (both as to origin and distribution) in Vertebrates generally, but where there are extra muscles of the orbit, such as have been already described in the Eighth Lesson, these muscles are supplied by the sixth pair of nerves.

It may be, however, that the whole of these nerves are quite blended with one division (the ophthalmic) of the fifth nerve, as *e.g.* in the Lepidosiren ; or the sixth nerve alone may form one with the fifth, as in the Bull-frog and others ; or the third and fourth nerves may unite to form a common trunk, as in the Lamprey, the external and inferior rectus, together with the inferior oblique, being furnished with nerves by the first (ophthalmic) branch of the fifth nerve. Finally, the whole of these three nerves may abort, as in the Myxine.

22. The FIFTH NERVE, a very large and important one, passes forth from the side of the mid-brain, and, after swelling out into what is called the Gasserian ganglion, divides into three nerves, called respectively the *ophthalmic*, the *superior maxillary*, and the *inferior maxillary*.

The ophthalmic nerve passes through the spheno-orbital fissure. It subdivides into various branches, of which we may note—(1), the *nasal* branch, which skirts the ethmoid, and (2), the *lachrymal* branch, which passes along the outer side of the orbit to the lachrymal gland.

The superior maxillary nerve passes through the foramen rotundum and infra-orbital foramen, and goes to the nose, eyelid, upper lip, and teeth of the upper jaw.

The inferior maxillary nerve passes out through the foramen ovale, and goes to the tongue, salivary glands, and adjacent parts, and, traversing the canal of the mandible, supplies the teeth of the lower jaw with nerve filaments.

The tongue, although an organ of special sense, will be more conveniently described amongst the other alimentary structures in the Eleventh Lesson.

A remarkable constancy exists as to the fifth nerve in Vertebrates, except that in some lower forms it blends, as has been said, with the sixth nerve or with all the orbital nerves, and, as we shall find, also more or less with the seventh. The points of exit from the cranium may differ as to details even in man's own class, as has been indicated in describing the foramina of the skull in the Lesson on that part of the skeleton.

Comparing the essential characters of this nerve and the distribution of its branches in man, with its condition in the lowest and in embryonic forms, it appears that the ophthalmic nerve is the one which skirts, by its branches, externally the trabecula cranii of its own side, and internally the palato-quadrate arch; and similarly that the upper and lower maxillary branches may be considered as two branches of one whole, which divides to skirt the palato-quadrate arch inferiorly (or posteriorly) with one branch, and the mandibular arch superiorly (or anteriorly) with the other.

23. The next nerve, as ordinarily described in human anatomy, is a part of the seventh, which is said to be divided into a *portio mollis* and a *portio dura.* In this book the latter nerve (the portio dura) will be spoken of exclusively as the seventh nerve, and the portio mollis, or AUDITORY NERVE, may now be considered.

This portio mollis is not, like the so-called optic and the olfactory nerves, a cerebral outgrowth, but still it is a peculiar nervous formation applied exclusively to minister to a special sense, namely that of hearing.

The EAR of man has been described with great care in the "Elementary Physiology," Lesson VIII. §§ 15—30, so that here it will be only necessary to notice the development of the parts of the human auditory organ.

The ear, like the eye, is formed by an involution of the skin, but this is not supplemented by an outgrowth of the

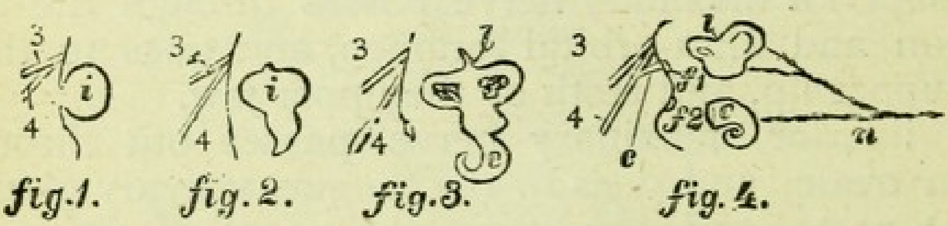

FIG. 345.—DIAGRAM TO ILLUSTRATE THE DEVELOPMENT OF THE EAR IN SUCCESSIVE STAGES FROM FIG. 1 TO FIG. 4.

i, involution of integument forming a sac which afterwards becomes the membranous labyrinth; *c*, inferior process of the sac (*i*) which detaches itself and becomes the cochlea; *l*, upper part of sac which forms the semicircular canals; *n* auditory nerve; f^1, fenestra ovalis; f^2, fenestra rotunda; *st*, stapes, or columella auris; 3 and 4, summits of third and fourth (or mandibular and hyoidean) arches, against the upper part of which the stapes abuts, being an outgrowth from the region of the fenestra ovalis.

brain, so that it is only the outer part of the eye which is parallel in development to the ear.

The outer margin of the involution contracts, and so forms a closed sac placed beside the hind-brain, and above the end of that visceral cleft which separates the mandibular and hyoidean arches.

The closed sac sends out four processes, three of which become the three *semicircular canals*, while the fourth detaches itself, coils round, and becomes the *cochlea*. In the meantime tissue on the inner side of this "labyrinth" changes into the true auditory nerve, and thus places that structure in direct communication with the brain.

This merely membranous labyrinth is afterwards enclosed in dense bone—as before mentioned in describing the petrous part of the temporal bone—the bony investment leaving two apertures (termed respectively the *fenestra ovalis* and the *fenestra rotunda*) besides those minute foramina (at the bottom of the meatus auditorius internus) through which the filaments of the auditory nerve enter.

The visceral cleft meanwhile becomes differentiated into (1) an outermost part (the meatus auditorius externus) invested beneath by the tympanic bone, and closed within by the tympanic membrane or drum of the ear; (2), a median part (the tympanic cavity) bounded externally by the drum of the ear, and traversed by the auditory ossicles, the *malleus*, *incus*, and *stapes*; (3), an innermost part (the Eustachian tube)—a straight, simple canal—opening internally at the side of the roof of the pharynx by a rather wide aperture.

The upper ends of the mandibular and hyoidean arches become differentiated into the malleus and the incus respectively, the stapes being, as it were, an outgrowth going from the fenestra ovalis to the upper part of the hyoidean arch.

From the posterior margin of the hyoidean visceral arch a membrane grows out which becomes the external ear, the *concha* or *pinna*, which presents various parts, amongst the smaller yet more noteworthy of which are the soft depending portion, or *lobule*, and the little conical prominence (called the *tragus*) which projects backwards over the external opening of the ear.

Such being the condition and development of the ear in man, it remains to estimate its peculiarity and the nature of some of its component parts by a brief survey of the more remarkable conditions which the organ presents in other Vertebrates.

In that he possesses an internal ear, he agrees with all Vertebrates except the anomalous Lancelet, nor (with this exception) does the organ of hearing ever become atrophied in the way which we have seen such atrophy to occur occasionally with the organ of sight.

A labyrinth composed of three semicircular canals is also almost universal, the only exceptions being the Lampreys, which have but two canals, and the Myxine, which has but one—the whole organ in it consisting of but one circular canal.

A *cochlea* is present in all Mammals and Sauropsida, but only in the former is it spirally coiled, and not in all of them, it bein; but slightly twisted in Monotremes as in Sauropsidans. In man's own division, the Monodelphous Mammals, the cochlea may be less coiled than in him, namely only one and a half times (*e.g.* the Hedgehog); or more so than in him, as in the Paca, which has it coiled five times.

The MEMBRANOUS LABYRINTH may, as in Fishes, be enclosed by hard structures (bone or cartilage) in such a way that no fenestræ are left unsolidified, but at the same time the bony chamber (or otocrane) may be widely open internally, as *e.g.* in the Carp, Cod, &c.

The opening of the primitive involution of the integument to form the ear may persist throughout life, as in the Rays, where it opens on the top of the head by a valvular aperture.

The external auditory meatus may be quite absent, as in Fishes and Tailed-Batrachians, and the tympanic membrane may appear on the surface of the cranium (though covered with a layer of skin), as in many Frogs and Lizards.

The internal part of the primitive cleft (*i.e.* the Eustachian tube) may be absent, as in Fishes; or the two tubes may unite into a single and median aperture, as in Birds and the Toad *Pipa;* or they may open (as in the Crocodiles) by three apertures—one median and two lateral ones—each lateral Eustachian tube forming a singularly complex and contorted canal. They may have narrow openings into the pharynx, as in the higher Vertebrates, or wider ones, as in Frogs.

The *auditory ossicles* may be very different from those of man in form and relative size. Thus their relations have been asserted to be as follows:—

In the malleus of man the *processus gracilis* creeps down, as it were, to the Glasserian fissure, but it remains much smaller than the manubrium. As we descend in the animal scale we find these proportions reversed, till in the Echidna the very large malleus has an enormous processus gracilis, which descends in close contiguity to the lower jaw. In the Sauropsida the enormous malleus becomes segmented, one portion constituting the os quadratum, and the other forming the os articulare of the mandible.

In osseous Fishes a yet further segmentation occurs, as we find in addition a third bone, called the *meta-pterygoid.*

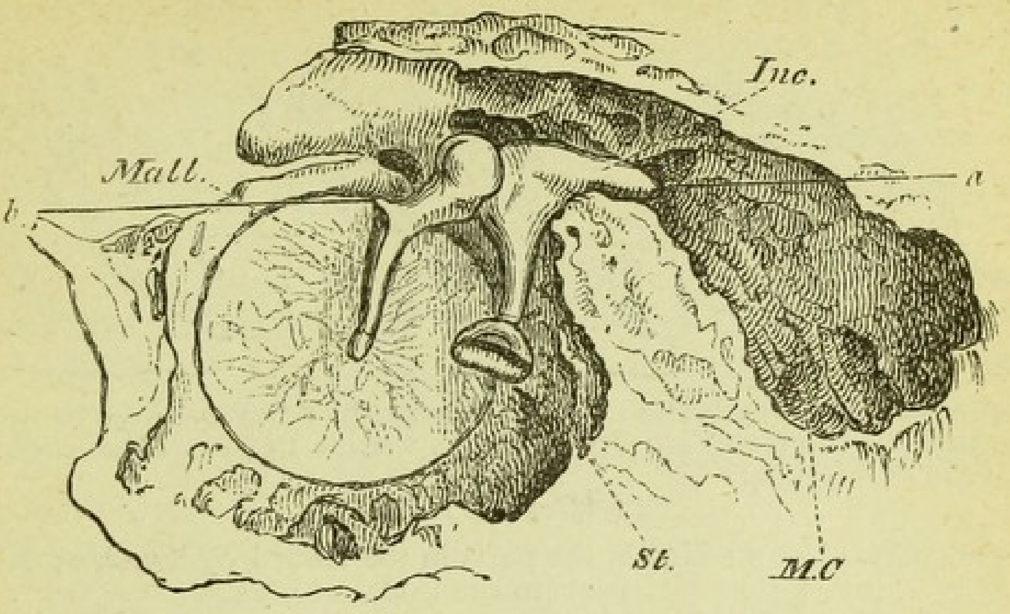

FIG. 346.—THE MEMBRANE OF THE DRUM OF THE EAR, seen from the inner side, with the small bones of the ear; and the walls of the tympanum, with the air-cells in the mastoid part of the temporal bone.

MC, mastoid cells; *Mall,* malleus; *Inc,* incus; *St,* stapes; *a b,* lines drawn through the horizontal axis on which the malleus and incus turn.

The incus becomes relatively smaller as we descend to the Sauropsida, and the stapes appears as a little straight ossicle (the *columella auris*) coming to the incus from the fenestra ovalis as usual. In Fishes, however, where there is no fenestra, there is no such ossicle, and the representative of the incus (*i.e.* the highest part of the hyoidean visceral arch) is a very large bone termed the *hyo-mandibular.*

Thus, if this interpretation be correct, it is plain that our comprehension of man's auditory ossicles would be very imperfect if studied only in man himself.

The three little auditory bones, the malleus, the incus, and the stapes, instead of being all similar in nature as in function, are singularly different.

The malleus is, as it were, the upper part of the lower jaw, separated, reduced in size, and taken into the ear through the Glasserian fissure, and applied to the assistance of a special sense.

The incus is the extreme summit of the anterior cornu of the os hyoides, separated and also applied to a similar purpose.

The stapes is quite different in nature, being a small portion of the cranial wall which has grown out, become separated, and secondarily connected with the upper part of the hyoidean visceral arch.

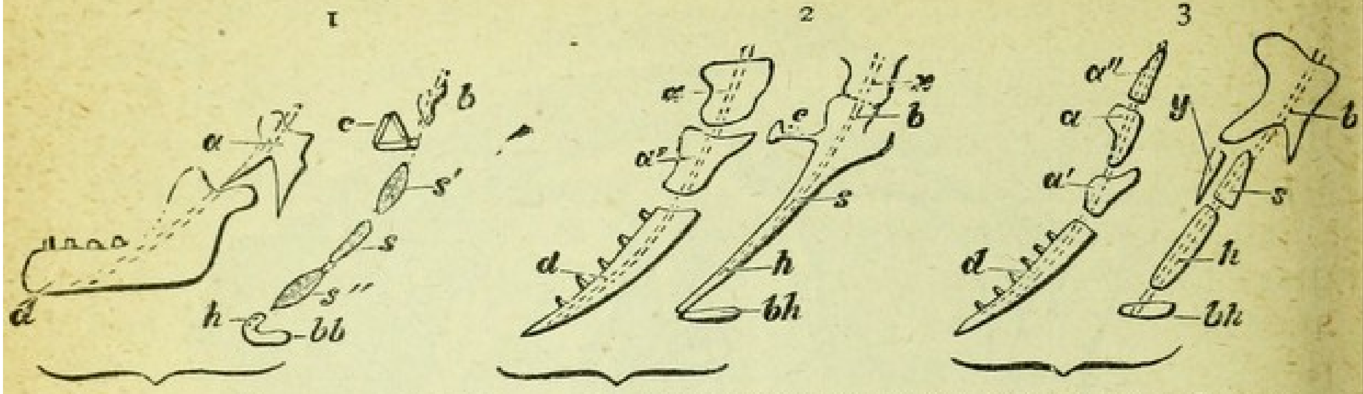

FIG. 347.—DIAGRAM ILLUSTRATING THE DIFFERENT DEVELOPMENTS IN SAUROPSIDANS AND ICHTHYOPSIDANS OF PARTS WHICH IN MAMMALS BECOME THE AUDITORY OSSICLES.

(*After Huxley.*)

No. 1, the parts in Man ; No. 2, the parts in the Lizard *Sphenodon* ; No. 3, the parts in the Cod.

a, malleus, or quadratum ; *a'*, the segment of it called os articulare ; *a''*, the segment of it called meta-pterygoid ; *b*, incus—in the Lizard *Sphenodon* that part of the continuous cartilage which answers to man's incus—in the Cod, the hyo-mandibular ; *c*, the stapes—columella auris in *Sphenodon ; d*, the dentary piece of the lower jaw ; *s*, stylo-hyoid, or, in *Sphenodon*, that part of the continuous cartilage which answers to it ; *s'*, the stapedius muscle ; *s''*, the stylo-hyoid muscle ; *bh*, the basi-hyal, or body of the hyoid ; *h*, the corniculum of the hyoid—in the Cod, called cerato-hyal ; *y*, symplectic.

The *external ear*, or pinna, may be entirely wanting, as in the Whales and in all below the Crocodiles, in which latter animals it is represented by a slight fold of skin.

On the other hand, its proportions may greatly exceed those of man, and, in the little Bat *Plecotus*, may equal in length the entire trunk. Moreover, the tragus may be (as in the Insectivorous Bats) so largely developed as to look like a second pointed ear standing up inside the normal one.

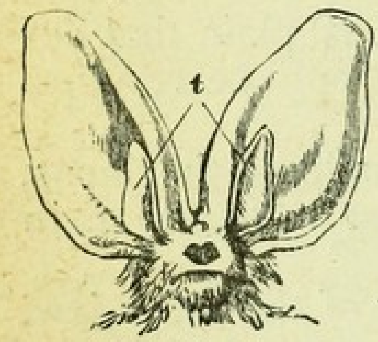

FIG. 348.—HEAD OF THE COMMON LONG-EARED BAT (*Plecotus auritus*).

t, the tragus of each ear.

A lobule is almost peculiar to man, though a rudiment of it is found in the Gorilla.

24. The portio dura of the SEVENTH NERVE (the *facial*) arises from the posterior division of the hind-brain, appearing at the posterior margin of the pons Varolii. It enters the internal auditory meatus, and, piercing the petrous part of the temporal bone, bifurcates, and one part comes out at the stylomastoid foramen. This part is distributed to the ear-scalp and

the muscles of the mouth, nose, and eyelids, and to the skin of the neck; it also sends a long and slender branch to the stylo-hyoid muscle. The other part, called the *chorda tympani*, comes out at the inner side of the Glasserian fissure, skirts the processus gracilis of the malleus, and runs along within the mandible to the sub-maxillary ganglion, in close juxtaposition with a branch of the third division of the fifth nerve.

These relations are constant, so that the seventh nerve divides into two branches, which respectively go to the anterior and posterior boundaries of that visceral cleft which divides the mandibular and hyoidean arches. In some of the lower Vertebrates the fifth and seventh nerves are much blended, and the two may, as in the Frog, be completely united at the large ganglion at the root of the former.

25. The EIGHTH NERVE is a very complex structure, and consists of at least three nerves united together, and all arising from the medulla oblongata and passing out by the jugular foramen.

The first of these, called the *glosso-pharyngeal*, supplies

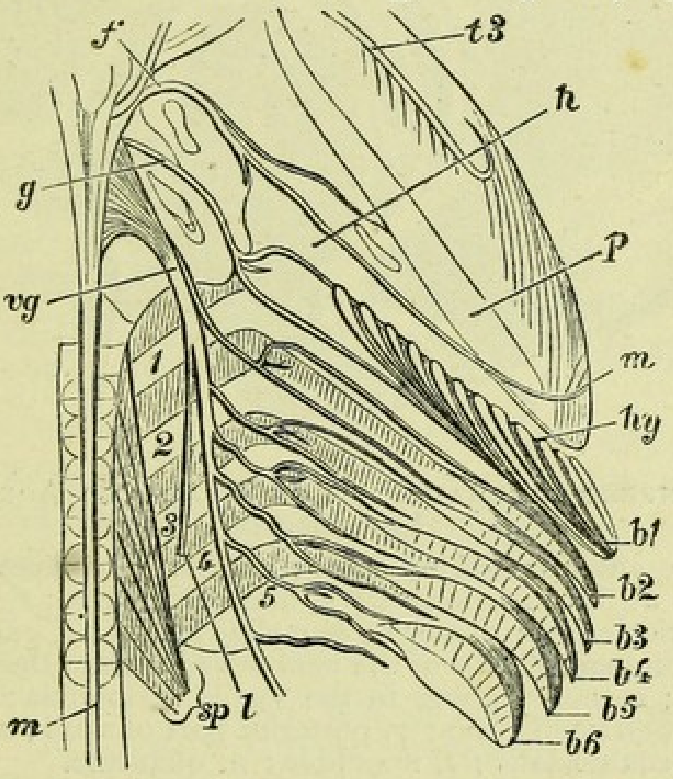

FIG. 349.—NERVOUS SUPPLY OF THE HINDER PART OF THE RIGHT SIDE OF THE HEAD OF THE SHARK *Hexanchus griseus*.
(*After Haeckel.*)

p, palato-quadrate arch; *h*, proximal part of the hyoidean arch; b^1—b^6, six branchial arches; 1—5, proximal parts of the branchial arches; *m*, spinal marrow; *f*, facial nerve; t^3, inferior maxillary (or third) branch of fifth nerve; *g*, glosso-pharyngeal; *m*, mandibular division of facial nerve; *hy*, hyoidean division of the glosso-pharyngeal; *vg*, nervus vagus; *l*, nervus lateralis; *sp*, spinal nerves.

the mucous membrane of the tongue and pharynx and some of the muscles of those parts. Its essential nature is revealed by lower forms, where (as *e.g.* in the Shark *Hexanchus*) it bifurcates (Fig. 349, *g*, *hy*, and b^2), and sends one branch to the posterior margin of the hyoidean arch, and another along the anterior margin of the first branchial arch. This fact may explain its pharyngeal distribution in man.

The second, called the *pneumo-gastric*, or *nervus vagus*, is the longest of all the cranial nerves, as it supplies not only the organs of the voice and of respiration, but also the

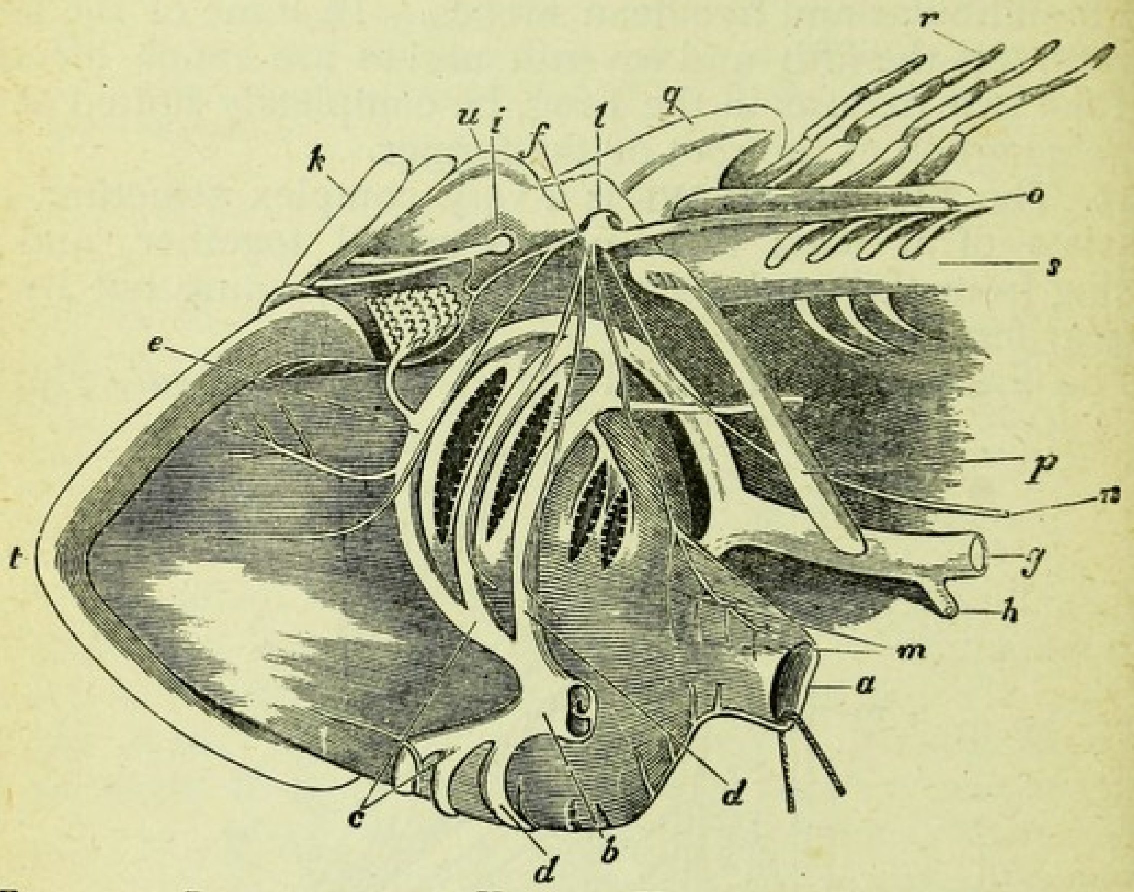

FIG. 350.—INFERO-LATERAL VIEW OF HEAD AND AORTIC ARCHES OF LEPIDOSIREN.

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 skull ; *r*, segmented neural spines ; *s*, chorda dorsalis ; *t*, mandible ; *u*, quadrate.

(*After Hyrtl.*)

heart and the stomach. It sends back two branches to the larynx, which are called "re-current," and the relations of which to the arterial trunks are different on the two sides of the body. The essential nature of this nerve is revealed by the lowest Vertebrates, where (as in Fishes) we find it made up of a great trunk, arising by many rootlets from the medulla, and giving off a branch to border the opposite sides of the successive branchial apertures, and then continuing on to the alimentary canal. It also, in Fishes, gives off a special nerve, called the *nervus lateralis* (Fig. 349, *l*, and Fig. 350, *o*), to the outer skin of the lateral body-wall, immediately beneath what is called the "lateral line." By very rare exception the two pneumo-gastric nerves may unite and run along the intestine to its extreme end.

The third part of the eighth nerve (named the *spinal accessory*) supplies the trapezius and sterno-mastoid muscles. It may be altogether absent, as is the case in Serpents, and in the whole of the Ichthyopsida.

26. The NINTH NERVE is called the *hypoglossal*. It arises by several roots from the medulla oblongata, and then passes out through the anterior condyloid foramen, and is distributed to the muscles of the tongue, the os hyoides, and the larynx. In Fishes this nerve is usually called the "first spinal;" and in fact the essential nature of the hypoglossal nerve is rather spinal than cerebral, being often closely connected with what is commonly reckoned the first spinal, even in Vertebrates above Fishes.

Thus we see that the so-called cranial nerves belong to two categories, (1) those of special sense, and (2) those which border the primitive visceral clefts and send off filaments to other structures.

The fifth, seventh, and eighth nerves belong to the second category; the third, fourth, and sixth nerves may be regarded as derived from the fifth.

The eighth nerve is a most complex one, the glosso-pharyngeal portion alone being made up of an undetermined number of cranial nerves related to those visceral clefts and arches which become obliterated in all Vertebrates above the Ichthyopsida.

27. The SPINAL NERVES arise in pairs from opposite sides of the spinal marrow. They are related in number to the divisions of the axial skeleton, or vertebræ, and (as has been said in describing that skeleton) they pass out of the neural canal either in the intervals between the neural arches, or by direct perforations of those arches.

Each nerve arises by two roots—one anterior (or ventral), the other posterior (or dorsal). The posterior, or dorsal, root has a ganglionic enlargement (Fig. 339, *B*, *Gn*).

After leaving the neural canal each nerve divides into two conspicuous branches—one dorsal, the other ventral; but

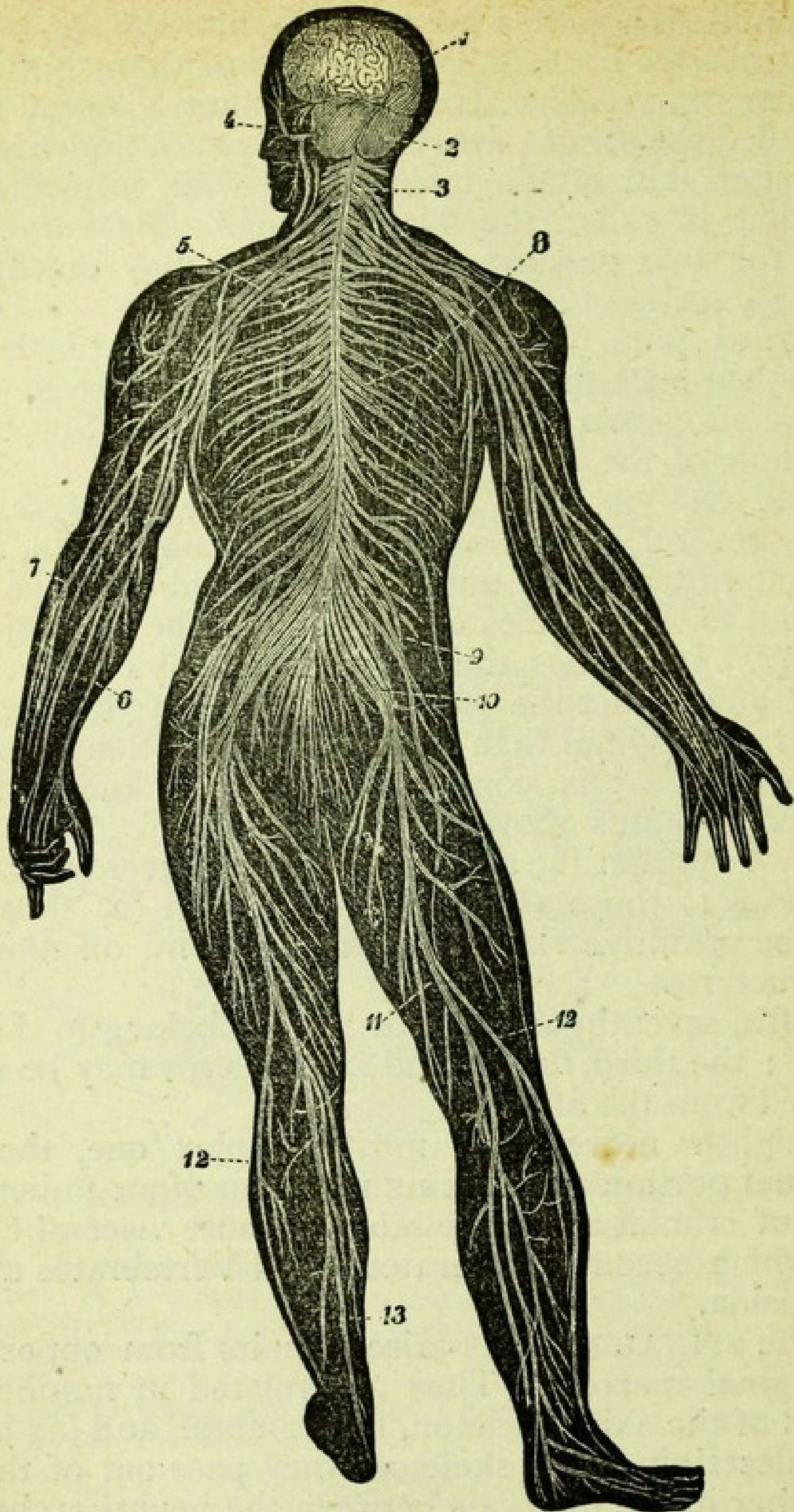

FIG. 351.—GENERAL VIEW OF THE NERVOUS SYSTEM, viewed from behind.

1, cerebrum; 2, cerebellum; 3, cervical part of spinal marrow; 4, facial nerve; 5, brachial plexus; 6, median nerve; 7, a cutaneous nerve between which and the median nerve is the ulnar nerve—the radial (or musculo-spiral) nerve is seen descending the outer sides of the other fore-arm; 8, intercostal nerves; 9, lumbar plexus; 10, sacral plexus; 11, great sciatic nerve dividing into (12) the peroneal nerve—a principal branch of which is the anterior tibial nerve and (13) the popliteal or posterior tibial nerve.

besides this each gives off a minute filament (or a pair) to what is called the sympathetic system.

Of these two series of conspicuous branches, it is the ventral one which constitutes the nerves of the limbs. In the part of the body intervening between the pectoral and pelvic limbs, the ventral branches pass, in the thoracic region, between the ribs, as intercostal nerves; and in the abdominal region they run along between the internal oblique and the transversalis muscles.

It may be, by rare exception (as in the Ganoid Fishes), that the dorsal and ventral nerves, instead of being the bifurcating branches from a common root, are distinct nerves, each arising by its own root.

28. The NERVES OF THE ARM of man result from the intermixture, in what is called the *brachial plexus*, of the ventral branches of the four lowest cervical and the first dorsal nerves.

Issuing from the plexus, the most noteworthy nerves are the *ulnar* and *median*, which supply the pronator muscles and the flexors of the digits, and the *musculo-spiral* nerve, which supplies the supinator muscles and the extensors of the digits. The last-mentioned nerve comes round the back of the humerus to pass along towards the radial side of the front of the fore-arm. The median nerve, passing down the inner side of the upper arm, crosses to the front of the elbow and descends along the middle of the fore-arm. The ulnar nerve passes down between the olecranon and inner condyle of the humerus.

The position and number of those spinal nerves which supply the limbs may be very different from what we find in man. Thus, in Birds (which often have so many cervical vertebræ) the limb nerves are more remote from the head, while in Batrachians they are closer to it, and the brachial plexus may be formed but by two.

Nevertheless a general resemblance exists with regard to the nerves of the arm in all Vertebrates above Fishes, excepting, of course, those animals in which the pectoral limbs are absent or rudimentary.

In Fishes, however, we find very different conditions. (1) We may have, as in many osseous Fishes, but the first two pairs of spinal nerves for the supply of the pectoral fin; or (2), as in the Rays, we may have an enormous number of spinal nerves (much more than half those of the entire body), which, though collected and connected in different bundles, do not form a definite interlacement like the brachial plexus of man and the higher Vertebrates.

29. The NERVES OF THE LEG of man result from the intermixture, in what is called the *lumbar* and *sacral plexuses*, of the ventral branches of the four lowest lumbar nerves and of the four highest sacral nerves, five of these (the lowest lumbar and four sacral) contributing to form the sacral plexus.

Issuing from the lumbar plexus is the *crural* nerve, which goes to the front of the thigh and to the pectineus and sartorius muscles; while from the sacral plexus issues the largest nerve in man's body—the great *sciatic*, which divides into the *anterior tibial*, supplying the extensors of the foot, and the *posterior tibial*, supplying its flexors and thus apparently answering to both the median and ulnar nerves of the arm.

The crural nerve passes out in front of the pelvis, but the sciatic passes out behind it, between the great trochanter and the tuberosity of the ischium. Its flexor branch (the posterior tibial) passes on behind the knee-joint and under the internal malleolus, while its extensor branch runs between the gastrocnemius and biceps muscles round the head of the fibula, and descends in front of that bone.

The lumbar plexus exists in almost all Vertebrates above Fishes, but it may be formed of only two nerves, as in *Menopoma* and the Crocodile, and it may be more separated from the last nerve of the sacral plexus than in man, as is the case in Birds.

The sacral plexus, similarly constant, may be formed by but three nerves, as in *Menopoma*, or but two, as in *Proteus;* or it may, on the contrary, as is the case in Birds, be formed by the concurrence of as many as six spinal nerves. As many as four or five of these issue from foramina of the sacrum preaxial to those sacral vertebræ which are furnished with expanded transverse processes, or sacral ribs (see Less. II. p. 56).

In Lizards also the sacral plexus is mainly formed by nerves issuing from vertebræ pre-axial to those which articulate with the iliac bones—two out of the three nerves which combine to form the sciatic nerve being thus conditioned. If therefore we take the nerves as our standard of comparison, the so-called sacrum of Lizards does not exactly answer to that of man and Mammals generally, but is relatively a somewhat more post-axial structure.

A general agreement is again shown with regard to the nerves of the leg in all Vertebrates with developed hind limbs, above Fishes. It may be, however, as *e.g.* in *Menopoma*, that the posterior tibial is divided into two nerves, thus making the correspondence between the nerves of the pectoral and pelvic limbs more unmistakable than it is in man, in whom but a single leg-nerve (the posterior tibial) answers to both the median and ulnar of the arm.

In Fishes we find great variety as to the nerve supply of the hinder members (ventral fins). Thus, small branches from the ventral nerves of the fourth pair of spinal nerves may be distributed to the ventral fins, as is the case in thoracic and jugular Fishes ; or from the seventh and eighth spinal nerves, as in the Carp ; or finally, as in the Sharks and Rays, the ventral fins may be supplied by more posterior spinal nerves, and by as many as six of them.

In man the nerves for the extensor muscles pass out post-axially as regards the scapula, pre-axially as regards the pelvis ; but both the corresponding set of nerves may pass out post-axially, as *e.g.* in *Menopoma*.

30. The SYMPATHETIC SYSTEM is made up of an immense number of small nerves and ganglia closely connected with the arteries and with the viscera, and proceeding from two longitudinal gangliated cords which extend upwards and downwards one on each side of the ventral aspect of the skeletal axis from the pre-sphenoid to the coccyx. The visceral nerves in passing to the various organs they supply, traverse those folds of membrane (the mesenteries) which, as we shall see, suspend the viscera from the backbone.

In the head, filaments of this system communicate with all the true cranial nerves (*i.e.* with all but the so-called "optic" and "olfactory" nerves), and below the head the successive ganglia unite with the corresponding spinal nerves by the filaments which, as before mentioned, pass from the latter to the sympathetic.

Thus, in fact, the sympathetic system may be but a series of internal branches of the spinal nerves of each side of the body. In this case each spinal nerve must be considered as dividing into three branches. One of these branches follows the line of the ascending dorsal lamina of the embryo—as a dorsal nerve. Another of these follows the line of the outer plate of the bifurcating ventral lamina of the embryo—as an abdominal nerve. The third branch—viz. the filament to the sympathetic and its continuation—follows the line of the internal plate of the bifurcating ventral lamina of the embryo. If, then, this view is correct, the sympathetic system essentially consists of all those branches of the cerebro-spinal system which originally pass down to the viscera in the inner plate of each bifurcating visceral lamina of the embryo, and which are represented in the adult by branches similarly extending into the mesentery,[1] and by their serial homologues.

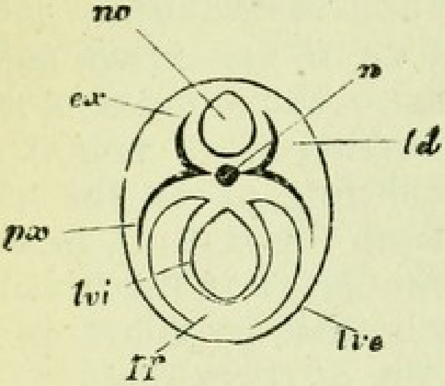

FIG. 352.—DIAGRAM OF THE DEVELOPMENT OF THE TRUNK AND ITS SKELETON, as shown in a section made at right angles to the trunk's long axis.

nc, neural canal ; *ex*, epaxial cartilages ascending to surround it ; *px*, paraxial cartilages descending in the plate, or layer (*lve*), external to *pp*, the pleuro-peritoneal cavity ; *lvi*, internal plate of the split ventral lamina.

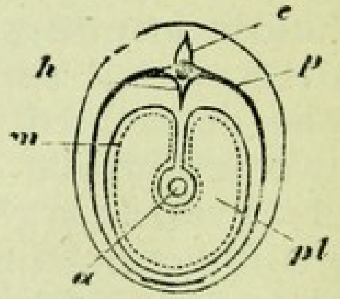

FIG. 353.—DIAGRAM OF THE FURTHER DEVELOPMENT OF THE TRUNK, as shown in a section similar to the last.

a, alimentary canal supported by a mesentery formed of the dorsal portion of the inner parts of the split wall of the embryonic ventral laminæ ; *e*, epaxial arch ; *h*, hypaxial arch descending in the median line in the root of the inner part of the split wall of the ventral laminæ ; *p*, rib, bifurcating proximally and abutting ventrally against the sternum, which thus completes the paraxial arch ; *m*, peritoneum, bounding on all sides *pl*, the pleuro-peritoneal space.

Moreover, these branches are connected together on each side (near their origins) by commissural nerve-fibres, and it is these two linear series of commissures (enlarged into ganglia at their successive points of junction) which constitute the two longitudinal gangliated cords before spoken of.

It is the presence of these commissural cords which makes so marked a contrast between the sympathetic system and the other branches of the spinal nerves, which in man exhibit no signs of such continuous longitudinal union. But an extended survey shows us that these latter (the undoubted spinal nerves) may also be connected together by similar axially extended commissural cords, for such do exist in the class of Fishes.

The sympathetic nerves of the viscera present three great complications, termed (1) the cardiac plexus, (2) the solar plexus, and (3) the hypogastric plexus : these are placed respectively above the heart, behind the stomach, and in the pelvis.

[1] See Lesson XI., p. 458.

In the existence and main characters of his sympathetic system man agrees with the members of the Vertebrate sub-kingdom generally; nevertheless, the sympathetic may be absent, as is alleged to be the case in the Marsipobranchs, and its place may be supplied (as in the Myxine) by an extension of the pneumogastric.

31. The contraction of muscular fibre in man is said to be accompanied by more or less electrical disturbance. This leads us to observe that certain organs may exist for storing up electricity so as by its discharge to administer severe shocks to creatures in the vicinity of animals possessing and making use of such structures. These ELECTRIC ORGANS are met with only in the class of Fishes, and are constructed of membranous chambers enclosing cellular plates, while special nerves ending in minute ramifications are distributed upon one and the same side of each of the plates. The arrangement of these plates may vary, as also the position of the organs and the source of their nervous supply. Thus, in the Torpedo there are two such organs, one on each side, near the head; while in the Electric Eel there are four, two on each side of the trunk and tail. In the Torpedo the nervous supply comes from the medulla oblongata, while in the Electric Eel it is furnished through the ventral branches of the spinal nerves. In the Torpedo the cellular plates are placed horizontally, in the Electric Eel vertically.

32. The most GENERALIZED CONCEPTION at present attainable of the nervous system of Vertebrates, and therefore of man, may perhaps be expressed as follows:—

There is a cylindrical cerebro-spinal axis with a median cavity ending anteriorly at a lamina terminalis, from each side of which lamina a secondary prolongation is developed. Besides nerves of special sense and of parts surrounding such special sense organs, the axis gives off a series of bifurcating branches which skirt each side the cranial arches (splanchnapophyses), from the trabecula to the last branchial inclusive.

Behind these bifurcating branches, there is given off a series of spinal nerves, and each of these nerves splits into three branches: (1), dorsal; (2), abdominal; (3), sympathetic.

Certain of the abdominal branches unite to supply limb nerves when limbs are developed. The abdominal sympathetic branches, constantly united by commissural filaments, pass down from the spine along the mesentery, and are distributed to the viscera.

LESSON X.

THE CIRCULATING SYSTEM.

1. The CIRCULATING SYSTEM comprises the various channels or vessels by which the nutritive fluid of the body—the blood—is conveyed to and from every part of the organism. These vessels are of various and very different sizes.

The largest and most complex part of the circulating system is the heart, which may be considered as the central portion, all the other channels being subsidiary to it. These latter may be divided into three categories: (A), the vessels taking blood from the heart—which vessels are called *arteries;* (B), the vessels taking blood towards the heart—which are the *veins;* and (C), the minute tubes (*capillaries*) which convey the blood to the tissues, and intervene between and connect the ends of the arteries and veins—being distinguished from both those kinds of vessels by the absence of muscular fibres in their walls.

In addition to these vessels, which with the heart constitute what may be called the true circulating system, there are yet other vessels, *lymphatics* and *lacteals*, which convey fluid from almost all parts of the body into the veins—to which they thus form as it were a supplementary addition.

The fluids these vessels convey into the veins are (1) the colourless portions of the blood which have exuded from the capillaries, and (2) nutritive juices from the walls of the alimentary canal.

All these parts have been so fully described—not only as regards their function, but also as regards their structure—in Lesson II. §§ 1—11 of "Elementary Physiology," as to render unnecessary much which must otherwise have been here detailed.

2. The HEART in man, its form, cavities, apertures, valves, &c., have all been described and figured in the "Elementary

Physiology," Lesson II. §§ 8, 9, and 10. Nevertheless, it may be well here to recapitulate certain leading facts.

The heart is enclosed in a shut sac—the *pericardium*—one of those closed membranous bags called "serous" from the serous fluid they contain, the largest of which is the "peritoneum." Not only the heart itself, but also the roots of the great vessels which spring from it, are invested by the pericardium.

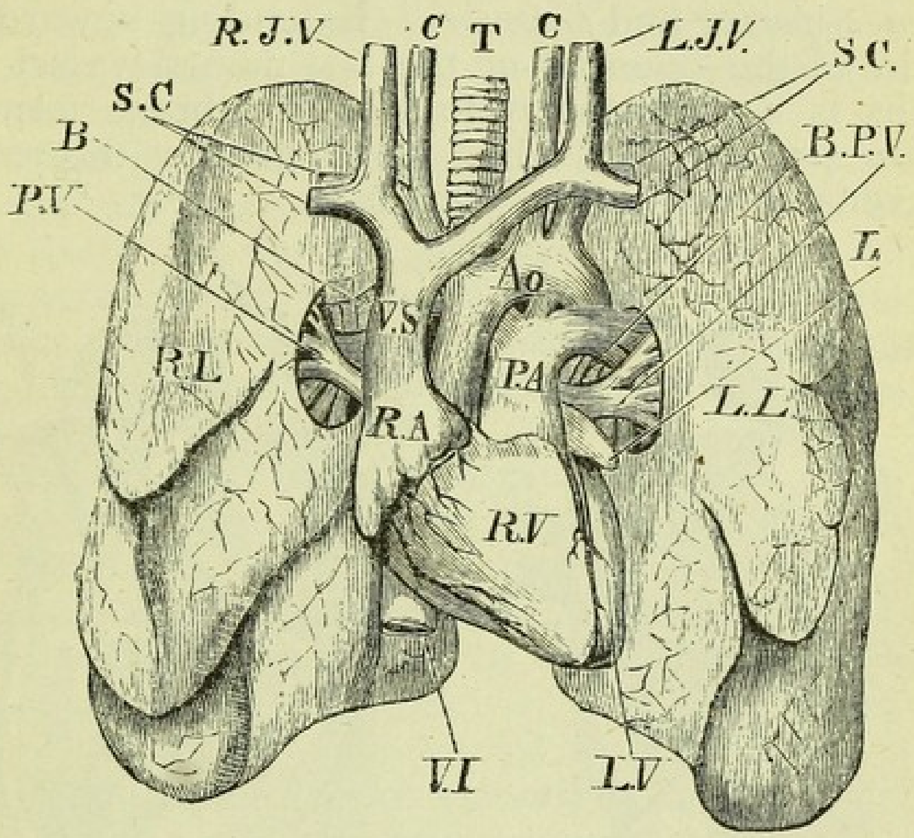

FIG. 354.—THE HEART, GREAT VESSELS, AND LUNGS. FRONT VIEW.

RV, right ventricle; *LV*, left ventricle; *RA*, right auricle; *LA*, left auricle; *Ao*, aorta; *PA*, pulmonary artery; *PV*, pulmonary veins; *RL*, right lung; *LL*, left lung; *VS*, vena cava superior; *SC*, subclavian vessels; *C*, carotids; *R* and *LJV*, right and left jugular veins; *VI*, vena cava inferior; *T*, trachea; *B*, bronchi. All the great vessels but those of the lungs are cut.

The heart is placed in the thorax between the lungs and entirely above the diaphragm. Of strong muscular structure, it is divided by a complete partition into two halves, a right and a left, and each half is subdivided, by an incomplete partition, into a smaller cavity or *auricle*, and a larger cavity or *ventricle*. The auricles alone give admission to blood into the heart; the ventricles alone expel blood from it.

The openings of the auricles into the ventricles are guarded by membranous valves which prevent regurgitation.

The valve which guards the entrance into the right ventricle is called *tricuspid*, and consists of three flaps attached by cords (*chordæ tendineæ*), as described in the "Elementary Physiology," Lesson II. § 10.

The left auriculo-ventricular opening is guarded by two flaps, forming what is called the *mitral* valve, from a fancied resemblance to a bishop's mitre.

The *right auricle* has on its left wall an oval depression called the *fossa ovalis*, and above and below this depression it receives blood from two large veins termed respectively the *vena cava superior* and *inferior*. Extending upwards from the margin of the opening of the last-named vessel to the fossa ovalis is a rudimentary fold of membrane termed the *Eustachian valve*. No other valve guards the entrance from the venæ cavæ into the auricle.

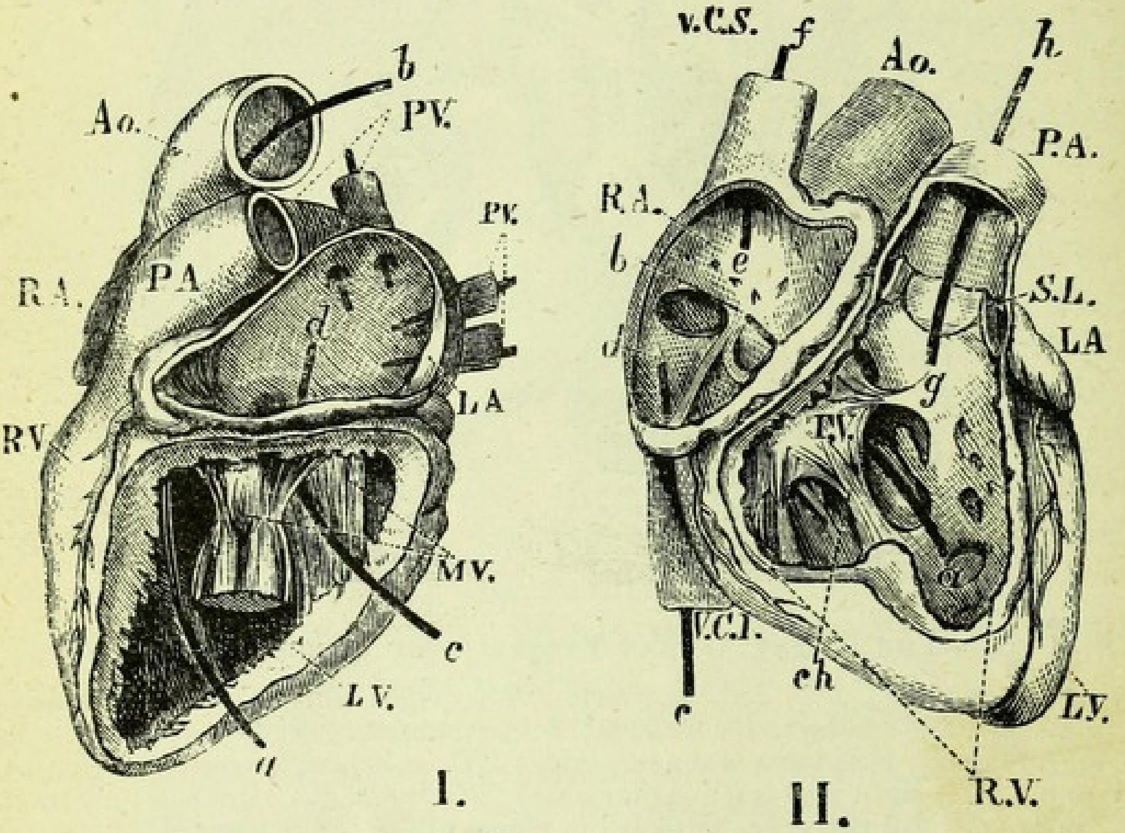

FIG. 355.—I. THE LEFT SIDE, AND II. THE RIGHT SIDE OF THE HEART DISSECTED.

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.

The *right ventricle*, besides the opening between it and the right auricle, has, at its upper part, another orifice; namely, that of the pulmonary artery (so called because it conveys blood to the lungs), which is guarded by three membranous folds, termed the *semilunar valves.*

The *left auricle* has no less than four orifices; namely, those of the four pulmonary veins. Their openings are not guarded by any valves.

The *left ventricle*, much thicker than any other chamber of the heart, has, besides the opening between it and the left auricle, one large aperture guarded by three crescentic flaps (the semilunar valves of the aorta), which valves resemble in structure those of the pulmonary artery.

3. At its first embryonic appearance the heart is merely a tube. In the DEVELOPMENT of the heart this tube becomes bent upon itself and divided into two chambers. The pre-axial chamber (nearest the head) becomes subdivided into the ventricles; the post-axial one (which alone receives blood from the body) becomes the auricles—which later grow to be pre-axial to the ventricles.

The further subdivision of each chamber into a right and left segment is accomplished by the ingrowth of two septal projections, which gradually become complete partitions, though the partition between the auricles is not complete at birth, an aperture existing then in that place which subsequently becomes the fossa ovalis.

The septum between the ventricles arises in such a manner as to divide the chamber giving origin to the pulmonary artery from the one whence springs that great primary artery, the *aorta.*

4. Turning now to survey the heart as it exists in Vertebrate animals generally, we find that different creatures exhibit permanently conditions which are but transitory in man.

In so far as the heart of man consists of four distinct cavities it agrees with that of all other animals not only of his own class, but also of the class of Birds together with the Crocodilian group.

It may be that the ventricles are but imperfectly divided, as is the case in all Reptiles except Crocodiles, in which latter they are completely separated.

The auricles themselves may also communicate permanently, as in some Chelonians; while, on the other hand, that trace of primitive division, the fossa ovalis, may be more completely obliterated than in man, as is the case in the Kangaroo.

Where (as in Batrachians) the heart has but a single ventricle, the root of the aorta is dilated into a *bulbus aortæ*, or *bulbus arteriosus*, which may be rhythmically contractile, as in Elasmobranchs, or not so, as in Teleosteans. Its entrance has valves variously conditioned in different animals.

The heart may consist of but two cavities, one auricle and one ventricle, as in Fishes. This reduction is, however, accompanied by a dilatation of the root of the aorta into a bulbus arteriosus, and of the termination of the venous channels at the heart into a *sinus venosus*.

Finally, the heart may consist of but a simple tube, as in the Lancelet, so often referred to.

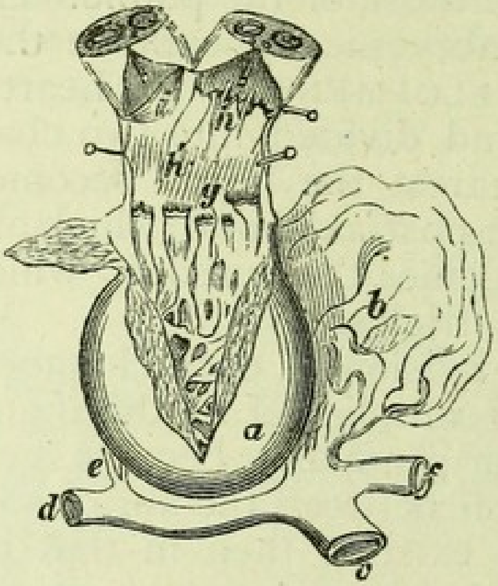

FIG. 356.—HEART OF CRYPTOBRANCHUS—OPENED ON ITS DORSAL ASPECT. (*After Hyrtl.*)

a, ventricle ; *b*, auricle ; *c*, vena cava ; *d*, right innominate vein ; *e*, coronary veins from the heart opening into the right innominate vein ; *f*, left innominate vein ; *g*, five fleshy, semi-lunar valves at the root of the bulbus aortæ ; *h*, three fleshy semi-lunar valves placed at the entrance of the right subdivision of the bulb ; *h'*, a prominence below the left subdivision of the bulb ; *i*, membranous semi-lunar valve at the root of the left subdivision of the bulb.

The envelope of the heart, the pericardium, may have its cavity continuous with that of the peritoneum, as in the Myxinoid and Elasmobranch Fishes.

The right ventricle may, as in all Mammals and Birds, give rise to the pulmonary artery only, or, as in Crocodiles, to an aortic arch also.

The valve separating that ventricle from the right auricle may, as in Birds, be muscular in structure, instead of membranous as in man.

In forms such as Frogs and most Reptiles (in which pulmonary arteries co-exist with a single or an imperfectly divided ventricle), special arrangements of valves cause the venous blood to be propelled into the pulmonary arteries, and mainly arterial blood into the aortic arches.

The heart may show marked signs even externally of the division into a right and left side, as in the Dugong, where its apex is deeply notched.

The heart may be more elongated than in man, as in Birds; or shorter and broader, as in Chelonians.

5. As has been said, two ARTERIES in man leave the heart, one proceeding from the right ventricle, the other from the left. These two channels ultimately end in distinct sets of capillaries, and thus there are two categories of arterial channels.

The great artery proceeding from the right side of the heart is termed *pulmonary*, and conveys the as yet unaërated blood for purification. It soon bifurcates into a right and a left branch, and these branches ramify in the substance of the right and left lungs respectively.

The arterial trunk proceeding from the left side of the heart is the largest of all, and is called the *great aorta*. It ultimately ends in capillaries distributed over the whole body, and constitutes the generally diffused (or systemic) arterial system. The aorta arises from the upper and back part of the left ventricle, whence it ascends forwards and to the right, and then curves backwards and towards the left, forming what is called the "*arch of the aorta*." It curves over the left bronchus, passing obliquely from the sternum to the spine. It then continues on in a nearly straight, vertical line, descending along the front of the vertebral column (rather on its left side) to the fourth lumbar vertebra, where it divides into the two common (or unsubdivided) iliac arteries—to be noticed shortly.

The aorta gives off from the convexity of its arch four great arteries, two going one to each side of the head, the two others to the two arms. Normally, however, the two vessels, going respectively to the right arm and right side of the head, are undivided for a short space, forming a large trunk called the *innominate* artery.

The two arteries for the head are each called "*common carotid*," and each bifurcates in the upper part of the neck into two branches, called respectively the *external* and the *internal carotid*.

The external carotid, besides physiologically important branches to the face and the sides of the head, sends one called the *thyroid* to the larynx, one called the *lingual* to the tip of the tongue, and one, the *posterior auricular*, which ascends (close to the styloid process, and passing through the

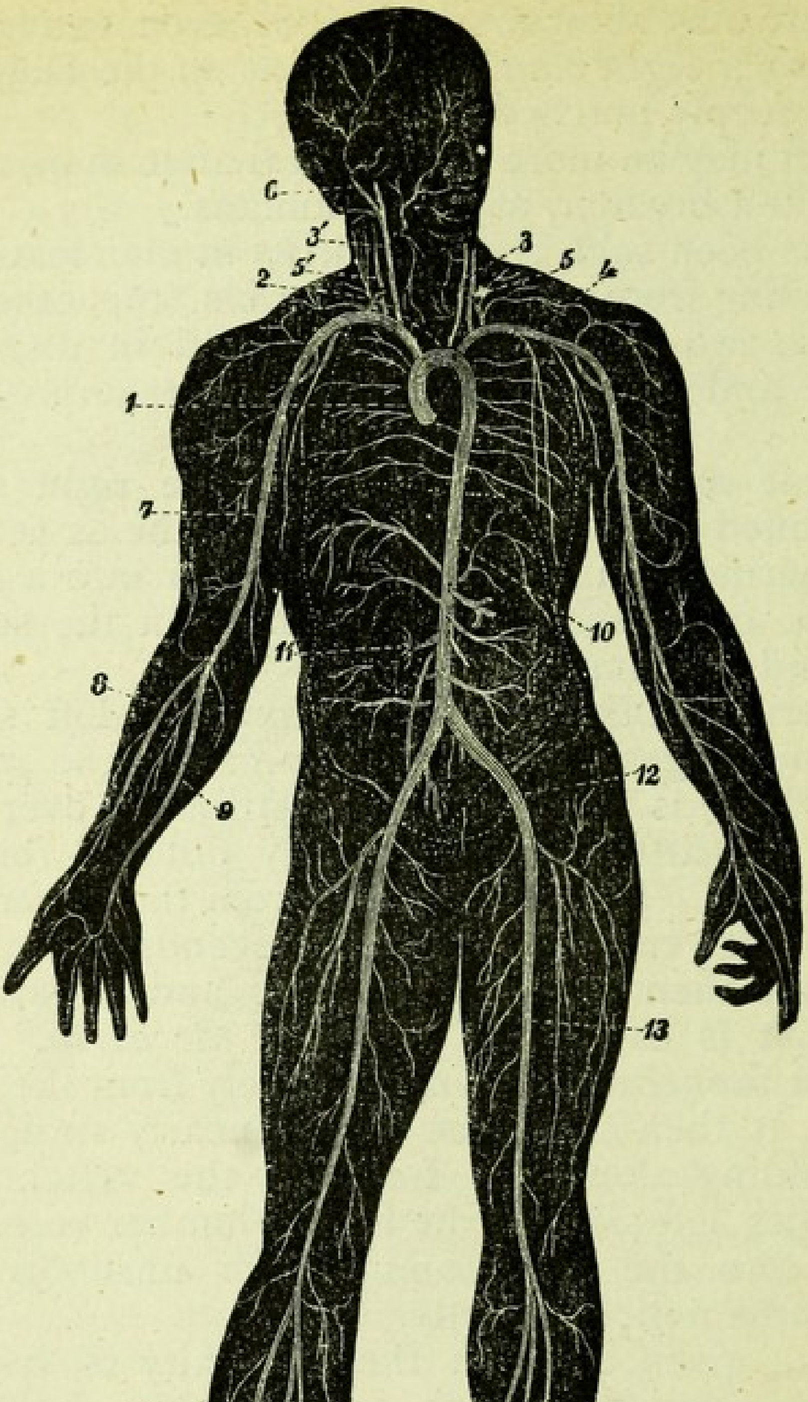

FIG. 357.—ARTERIAL SYSTEM OF MAN.

1, root of aorta; 2, its arch; 3, left common carotid artery; 3′, right common carotid; 4, left subclavian; 5, left vertebral; 5′, right vertebral; 6, temporal; 7, axillary; 8, radial; 9, ulnar (between the radial and ulnar arteries the interosseous artery may be seen); 10, descending aorta; 11, renal artery; 12, external iliac; 13, femoral; 14, anterior tibial; 15, peroneal; 16, posterior tibial.

stylo-mastoid foramen) to the tympanum. The *external carotid* then continues on, assuming the name of *internal maxillary*, and enters the spheno-maxillary fossa.

It gives off a number of branches, and amongst them a small one called the *tympanic* artery, which ascends through the fissura Glasseri to the tympanum, and there unites (or, as it is termed, *anastomoses*) with the posterior auricular; also the *vidian*, which passes back through the root of the pterygoid, and some branches to muscles. It then ends by dividing into the *descending palatine* and the *nasal arteries.* Of these two, the former descends the posterior palatine canal along with the palatine nerve, runs along the palate and enters the anterior palatine foramen where it anastomoses with the nasal artery. The nasal artery enters the nose through the spheno-palatine foramen (in company with the nasal nerve), sends twigs to the ethmoid, and, skirting the nasal septum, descends the anterior palatine canal to anastomose with the descending palatine as just mentioned.

The internal carotid transverses the petrous part of the temporal bone (as already noticed in the Lesson on the Skull), and, ascending beside the basi-sphenoid, anastomoses with its fellow of the opposite side at the pituitary fossa. While ascending the carotid canal of the petrous bone it gives off a small branch which anastomoses with the tympanic, vidian, and posterior auricular arteries. It terminates as the *ophthalmic* artery, which, entering the orbit by the optic foramen, skirts the inner wall of the orbit and distributes small branches in various directions.

The artery of each pectoral limb is termed the *subclavian*, and springs on the left direct from the aortic arch, but on the right from the innominate artery.

Each subclavian gives off an artery termed *vertebral*, which ascends through the perforations of the cervical transverse processes, and, entering the skull through the foramen magnum, unites with its fellow to form the *basilar* artery, which latter runs along the upper surface of the basi-occipital, gives off branches to the brain, divides, and anastomoses on each side with the internal carotid.

The subclavian gives off certain other branches, and then passes out of the trunk at the arm-pit as the *axillary* artery. It descends the arm on its inner side, between the biceps and the triceps muscles, and is then called *brachial.* At the elbow it sinks between the pronator teres and supinator longus, and bifurcates into the *radial* and *ulnar* arteries.

The ulnar gives off the *interosseous* artery from the interspace between the radius and ulna, and then passes along the inner side of the fore-arm to the hand, while the radial traverses the front of the fore-arm obliquely to the outer border of the wrist. These two arteries anastomose by a pair of palmar arches (one deeper than the other) which pass transversely between the ulnar and radial arteries. Of course, a variety of less important branches are given off at intervals, from the axillary artery and its subdivisions, along the whole extent from the axilla to the palm.

The great *descending aorta* gives off many small branches to the air-tubes, the œsophagus, and the spaces between the ribs, the last being called *intercostals.* After passing through the diaphragm, the aorta gives off several important branches to the viscera in the abdomen. Such are (1) the *cœliac axis*, which divides into a branch to the stomach, one to the spleen, and one to the liver—called *hepatic;* (2), the *superior* and *inferior mesenteric* arteries, which pass to the intestines by means of those folds of membrane (mesenteries), in which, as we shall see, the alimentary canal is slung; (3), the *renal* arteries, short and large, which pass, one on each side, to the two kidneys respectively; (4), the *lumbar* arteries, which repeat in the abdomen the intercostals of the thorax; and lastly, the *middle sacral*, which is a small median vessel running in front of the middle of the sacrum to the coccyx.

The *common iliac arteries* into which, as has been said, the abdominal aorta divides, after a short course themselves subdivide, each into an internal and external iliac artery.

The *internal* iliac is short, and distributes branches to the viscera and muscles of the pelvis, and also to muscles of the back. One small branch, called the *superior vesical*, passes to the side of the bladder, a fibrous cord connecting it with the back of the umbilicus or navel.

The *external iliac* passes out into the thigh, over the brim of the pelvis, and takes the name of *femoral.* It descends the middle of the thigh, between the vastus internus and adductor muscles, then dips into the popliteal space, beneath the gastrocnemius, and divides there into the *anterior* and *posterior tibial* arteries.

The *posterior tibial* passes down, as its name implies (*i.e.* behind the leg), and goes to the sole between the internal malleolus and the os calcis. It gives off, almost at its origin, a long branch, called the *peroneal* artery, which runs down behind the outer side of the leg.

The *anterior tibial*, having passed to the front of the interosseous ligament, extends down the front of the leg obliquely to the ankle, and then dips between the first and second metatarsals and anastomoses with the posterior tibial in a plantar arch, like the palmar arch before noticed. Many smaller branches are, of course, given off at intervals.

6. In their DEVELOPMENT the arteries exhibit some interesting phenomena.

The root of the aorta is, at a very early embryonic period, dilated into a bulb, and from it spring five vessels on each side (successively, however, as never more than three on each side exist at the same time), which arch round and meet together beneath the spinal axis to form the dorsal aorta.

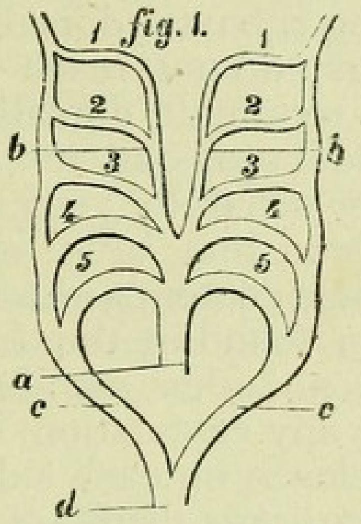

FIG. 358.—DIAGRAM REPRESENTING THE PRIMITIVE AORTIC ARCHES OF MAMMALS AND SAUROPSIDANS.

(*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.

The fourth arch on the left side persists, grows, and becomes the arch of the great aorta.

The third arch becomes the common carotid and part of the internal carotid arteries.

The two more pre-axially situate arches may not improbably become ultimately the tympanic and stylo-mastoid arteries.

The fifth arch gives rise to the pulmonary arteries; a communication between it and the great aorta, persisting for a considerable time, is called the *ductus arteriosus* (Fig. 367, *o*).

The descending dorsal aorta is at first double, but its two parts soon coalesce to form a single vessel. It extends posteriorly into a relatively large middle sacral artery, and gives off two considerable superior vesical (here called hypogastric) arteries, which go to the umbilicus and much exceed in size the primitive external iliac arteries.

7. The significance of these changes will appear from a consideration of the general condition of the arteries in the Vertebrate sub-kingdom.

A simple vesicular heart (*e.g.* in *Amphioxus*) may be continued on forwards (*i.e.* pre-axially) into a median artery, whence on each side diverge very many pairs of arteries, which ascend dorsally in contiguity with semi-cartilaginous arches, subservient to aquatic respiration. In this case the first arch on each side may continue uninterruptedly upwards till it meets its fellow, the two uniting above to form the anterior end of a long subaxial dorsal aorta. The ascending arches behind the first do not reach the aorta, but taper as they ascend till they terminate dorsally in a point, while each has a contractile dilatation at its base. Meanwhile the blood is collected by separate vessels (called veins) which spring from each branchial arch, and, growing larger as they ascend, pour their contents into the aorta.

This is a condition found in the Lancelet alone amongst the Vertebrata. In no other member of that sub-kingdom can aortic arches by any calculation, or at any period of life, be made to exceed eleven on each side.

In the Shark *Heptanchus* there are probably seven distinct branchial arches on each side.

From the *Lepidosiren* and *Ceratodus* we find there may be five branchial arches on each side; or there may be but four, as in the Perch.

In Fishes the arteries run on the outer side of the branchial arches (noticed in the Lesson on the Skull), and give off minute twigs to membranous structures termed gills (which will be described in the Twelfth Lesson). The blood is collected in the gills and conveyed to corresponding ascending vessels (called branchial veins) by minute twigs,[1] from which such ascending vessels take origin. The branchial arteries springing from the aortic bulb are not directly continuous, or connected by considerable branches, with the vessels joining the dorsal aorta—or branchial veins.

We may find, however, as in the Frog (at that age of its tadpole condition when the external gills begin to atrophy) that three branchial arteries from the bulb may co-exist

[1] See page 479, Fig. 405.

with three corresponding vessels going to the dorsal aorta, on each side—direct communications taking place between

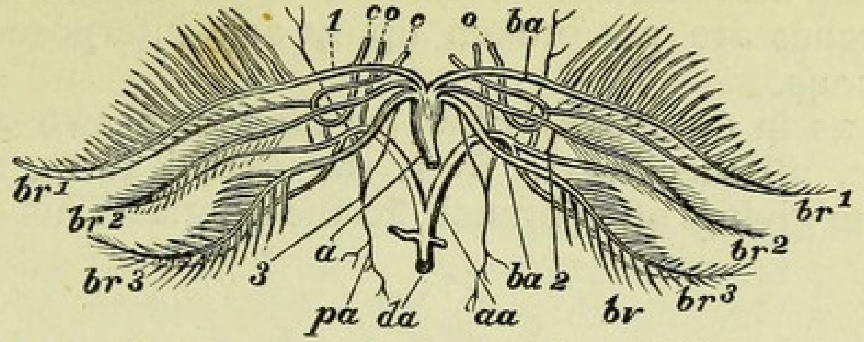

FIG. 359.—THE CIRCULATION OF A TADPOLE in its primitive stage, when nearly all the blood is distributed to the gills; the pulmonary arteries being quite rudimentary, and the vessel (or ductus Botalli) connecting together the branchial artery and vein at the root of each gill, being minute.

a, bulbus aortæ; *ba*, branchial arteries; br^1, br^2, and br^3, the three gills (or branchiæ of each side); *bv*, the branchial veins which bring back the blood from the gills—the hindmost 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 gives 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.

neighbouring arteries and veins (by what is called a *ductus Botalli*), in spite of each artery and vein minutely dividing in the gill beyond such points of communication.

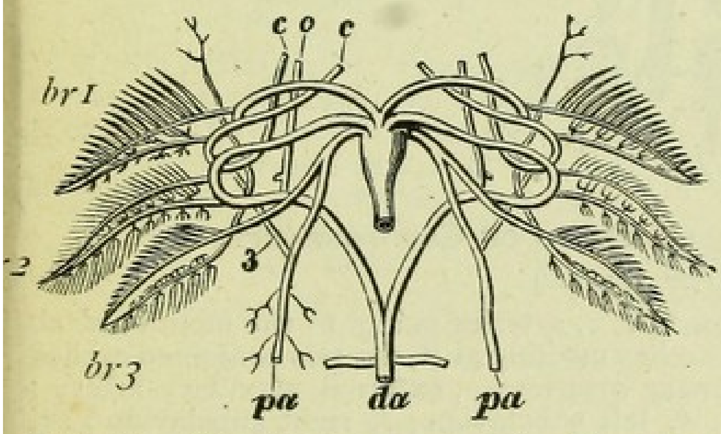

FIG. 360.—THE CIRCULATION IN A TADPOLE AT A MORE ADVANCED STAGE, when the gills have begun to be absorbed, the pulmonary arteries to increase, as also the connecting branches (at the root of the gills) between the branchial arteries and branchial veins.

The letters refer to the same parts as in Fig. 359.

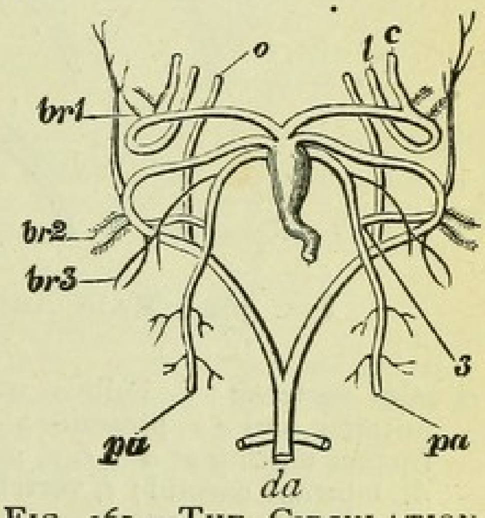

FIG. 361.—THE CIRCULATION IN A YOUNG FROG. Here the gills have been absorbed, and the blood passes directly from the heart to the head, the dorsal aorta, the lungs, and the skin.

The letters refer to the same parts as in Fig. 359.

Again, we may find, as in the adult Frog, three aortic arches on each side, whereof the first is the common carotid, the second meets its fellow of the opposite side above to form the dorsal aorta, while the third sends one branch forwards to the skin and another backwards to the lung. Here the aortic arches are not broken up by any interposed minute ramifications.

Again, as in *Cryptobranchus*, we may have two arches on each side, all meeting to form the dorsal aorta, and each hinder one giving off a branch to the lung. This condition

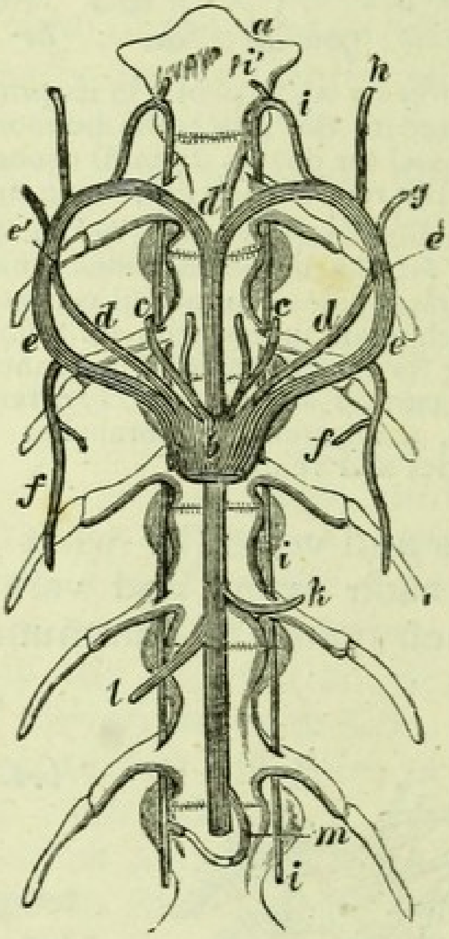

FIG. 362.—MAIN ARTERIAL VESSELS OF CRYPTOBRANCHUS. (*After Hyrtl.*)

a, atlas vertebra; *b*, bulbus arteriosus; *c*, *c*, arteries going to the mouth; *d*, *d*, anterior, and *e*, *e*, posterior aortic arches meeting at *e'*, the two conjoined arches further uniting at *d'*; *f*, *f*, pulmonary arteries; *g*, external maxillary artery; *h*, internal carotid; *i*, vertebral; *k*, left subclavian; *l*, right subclavian; *m*, spinal artery.

reminds us of that early stage in man (before noticed) when the ductus arteriosus connects the pulmonary artery with the aorta; only in *Cryptobranchus*, we find such a connexion persisting on both sides of the body, while in man the right great aortic arch has aborted.

We may also have, as in the Crocodile, two aortic arches —given off respectively from the right and left ventricles— uniting in the dorsal aorta; or finally, as in man's class and in Birds, we may have a primitively double aortic arch springing from the left ventricle only. Of this primitively double arch it may be the left half only (Fig. 366), which is developed, as in Mammals, or the right half only (Fig. 365), as in Birds.

When there are two aortic arches, one from each ventricle, these two arches may open into each other by a small foramen just outside the heart, as in Crocodiles.

Thus we see that man's earliest condition is most resembled by Fishes, which, however, may have a greater number of arches than are ever developed in him, and, moreover, these arches may all persist simultaneously. Also a variety of other conditions, transitory in man, may be permanently retained by animals of different kinds.

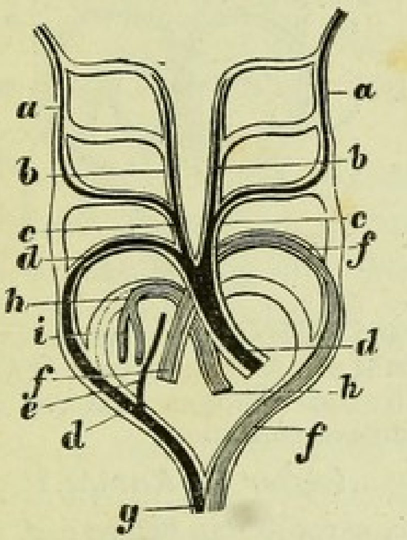

FIG. 363.—DIAGRAM REPRESENTING THE VESSELS AND AORTIC ARCHES OF A SNAKE, and the changes which the primitive condition (Fig. 358) has undergone. In this and the three following figures the parts left blank are those which abort.

(*After H. Rathke.*)

a, *a*, internal carotids; *b*, *b*, external carotids; *c*, *c*, common carotids; *d*, *d*, *d*, right main aortic arch; *e*, vertebral artery; *f*, *f*, *f*, left aortic arch; *g*, commencement of the descending aorta; *h*, *h*, pulmonary artery; *i*, remnant of a primitive aortic arch—or ductus Botalli—here a remnant of the right first aortic arch, No. 5 of Fig. 358.

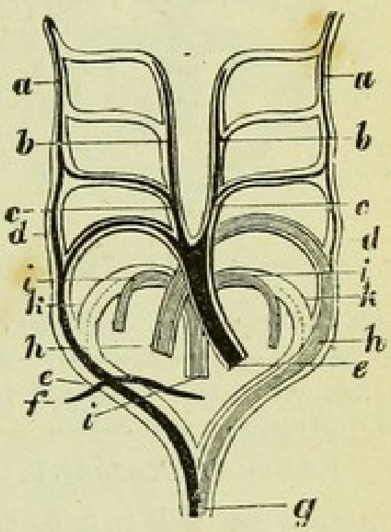

FIG. 364.—DIAGRAM REPRESENTING THE VESSELS AND AORTIC ARCHES OF A LIZARD, with the changes induced on the primitive condition.

(*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. 358.

The great arteries of the head and pectoral limbs may diverge from the aortic arch in different combinations in man's own class.

Thus they may all arise from the aorta in common as one great trunk, subsequently dividing, as in the Ox; or the left carotid, subclavian, and vertebral arteries may all arise separately from the aorta, as in the Dugong; or both common carotids may take origin in one trunk with the right subclavian, as in the Lion; or there may be two innominate arteries, each dividing into subclavian and carotid, as in the Hedgehog.

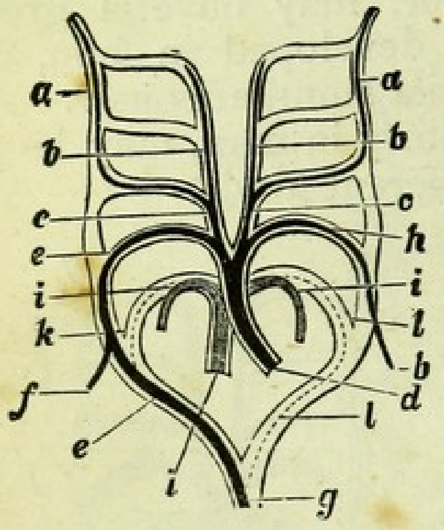

FIG. 365.—DIAGRAM REPRESENTING THE MAIN ARTERIES OF A BIRD (FOWL), with the changes induced on the primitive condition.

(*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,—Nos. 5, 5, of Fig 358.

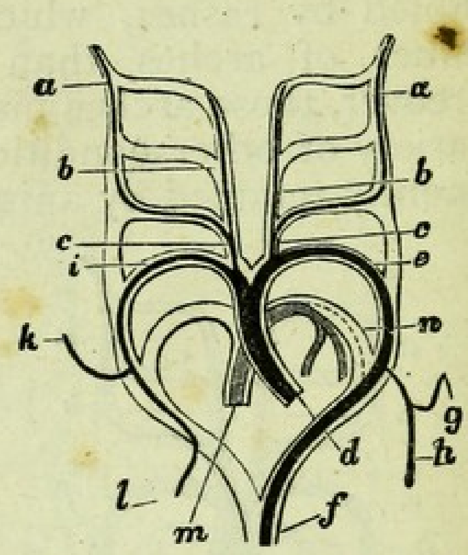

FIG. 366.—DIAGRAM REPRESENTING THE MAIN ARTERIES OF A MAMMAL, with the changes induced in the primitive condition.

(*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 (No. 5 of Fig. 358), the *ductus arteriosus* or ductus Botalli.

The two common carotids may ascend in close juxtaposition, as in Birds, and one of them may be much reduced in size, or even abort.

The vertebral artery, instead of passing through the cervical transverse processes, may perforate the neural laminæ, as in the Llamas.

The internal carotid may break up (inside the skull) into a network of small arteries (called a *rete mirabile*), as *e.g.* in the Ox.

Very different proportions may exist between the external and internal carotids, compared with what exists in man; and the course taken by each may vary in ways which characterize different groups of Mammals respectively.

The brachial artery may also break up into a number of small branches running side by side, as in the Sloths and Slow Lemurs.

The femoral arteries of the same animals are also similarly subdivided, and the same condition obtains in some other animals, *e.g.* the Echidna.

Great convoluted *retia mirabilia* may also be formed by the intercostal arteries, as we see in the Cetacea, *e.g.* the Porpoise.

A small *rete mirabile* (in what is called—as we shall see in Lesson XII.—a pseudobranchia) may be developed from the first (or hyoidean) aortic arch, as *e.g.* in *Lepidosiren* and osseous Fishes.

The intercostal arteries may be less numerous than the intercostal spaces, as in many Fishes.

The artery of the pectoral limb may be given off from the dorsal aorta, almost immediately after its formation, as in Fishes.

The dorsal aorta may dilate beneath each vertebral centrum of the abdomen, as in the Carp. It may give off many small branches to the kidneys, as in Fishes.

The internal iliac arteries may be given off distinctly from the external, as in the Kangaroo; and, as in the same animal, the middle sacral artery may be continued on of large size. The internal iliacs may be larger than the external, as in Birds.

The inferior mesenteric artery may abort in man's own class, as *e.g.* in the Kangaroo; and the two cœliac arteries may ramify in a sort of *rete mirabile*, as in the Porbeagle Shark.

8. The structure of the VEINS, their coats, valves, and the primary facts as to their conditions, have been noted in the first two Lessons of "Elementary Physiology," but the recapitulation of certain points is here necessary in order to avoid obscurity.

The veins, like the arteries, may be divided into two very unequal categories. The first of these comprises all those which aid in bringing back blood from all parts of the body to the right side of the heart: this consists then of the *systemic* veins. The second category includes only those veins which bring back blood from the lungs to the left side of the heart (the left auricle)—the *pulmonary* veins.

The systemic arteries (excluding *retia mirabilia* and gill structures from consideration) never, after dividing, reunite in a second aggregation.

The same is not the case with the veins, for certain of them, on their way back to the heart, break up into a minute network in the liver, whence they reunite and emerge in a large trunk, which then unites with the rest of the systemic venous system, and enters the heart. This secondary distribution of blood in the liver (the primary distribution there, being that of arterial blood by the hepatic artery) is what is called the *portal* circulation. The veins which diverge and become smaller in the liver—conveying venous blood into it—are called *portal* veins. The veins which collect themselves, unite and so become larger in the liver—conveying venous blood out of it—are called *hepatic* veins.

The blood from the brain and from within the cranium is collected on each side into the *internal jugular* vein, which passes out of the skull at the foramen lacerum posterius, and, descending the neck, joins the *subclavian* vein (of the same side of the body), which is the one bringing back the blood from the arm.

The blood from the outside of the head, from the muscles, teeth, &c., is collected on each side by the *external jugular*, which descends the neck and also opens into the subclavian.

A great trunk, the *innominate*, is thus formed (by the union of the two jugulars and the subclavian) on each side of the body, and the two innominate veins joining together form a yet greater trunk, called the *vena cava superior*, which opens, as has been already mentioned, into the right auricle.

The veins of the legs collect themselves together into a great vein, called the *external iliac*, which passes in (from the limb to the abdomen) over the front brim of the pelvis, and is joined by the *internal iliac*, bringing blood from the pelvic viscera.

This junction forms what is called the *common iliac* vein, there being, of course, one for each side of the body.

The two common iliacs unite and form one large and long ascending trunk, called the *vena cava inferior*, which perforates the diaphragm, and pours its blood also into the right auricle.

On its way this trunk receives blood from a *middle sacral* vein (corresponding with the similarly-named artery); from the kidneys (by short, wide renal veins); it also receives blood from certain other parts; and, finally, it receives blood from the hepatic veins, of which more must be said.

The veins from certain viscera, namely, the spleen, the mesentery, the intestines, and the stomach, finally unite into a single trunk—the portal vein, already mentioned. This enters the liver, and there breaks up and ramifies side by side with the ramifications of the hepatic artery, which latter brings arterial blood to that organ. This double supply of blood (one arterial, the other venous) is antagonized by but a simple set of efferent vessels, the hepatic veins. These, as before said, collect themselves together in the liver, meet and enlarge, and finally open obliquely into the vena cava inferior —a semilunar fold being visible at the lower border of the orifice of each vein.

There remains one more venous structure which may be noted, namely, what is called the *azygos* vein—an absurd designation, as there are really two such veins, though that on the right side is much the larger.

The right azygos communicates with the vena cava soon after its own origin, and ascends on the right side of the vertebral column, receiving venous branches called *lumbar* veins and *intercostals*. It originates below in the lumbar veins and terminates above in the vena cava superior.

The left azygos is similar, except in size and in that it opens above into the left innominate vein.

The two azygos veins communicate by a transverse branch passing behind the œsophagus, and it is here that the left vena azygos is said (in works on human anatomy only) to terminate—the part above this junction, and intermediate between it and the innominate vein, being spoken of in Anthropotomy as the *left superior intercostal vein*.

9. In their DEVELOPMENT the veins of man undergo remarkable modifications.

The first veins to appear are a pair which come from the intestine and ventral region to the heart, and lay the foundation of the portal and hepatic veins. These primitive veins are called *omphalo-meseraic;* they unite and dilate into a venous chamber (called *sinus venosus*) before entering the heart.

Two other venous trunks appear on each side, beneath the primitive skeletal axis, and each sends down a vein (the *ductus Cuvieri*) which opens also into the sinus venosus.

The part of each trunk which runs backwards from the head to the ductus Cuvieri is called the *anterior cardinal vein*. The part of each trunk which runs forwards from the hind part of the body to the ductus Cuvieri is called the *posterior cardinal vein*.

Another vein, called the *umbilical*, comes from the anterior abdominal wall and from other parts, and joins the omphalo-

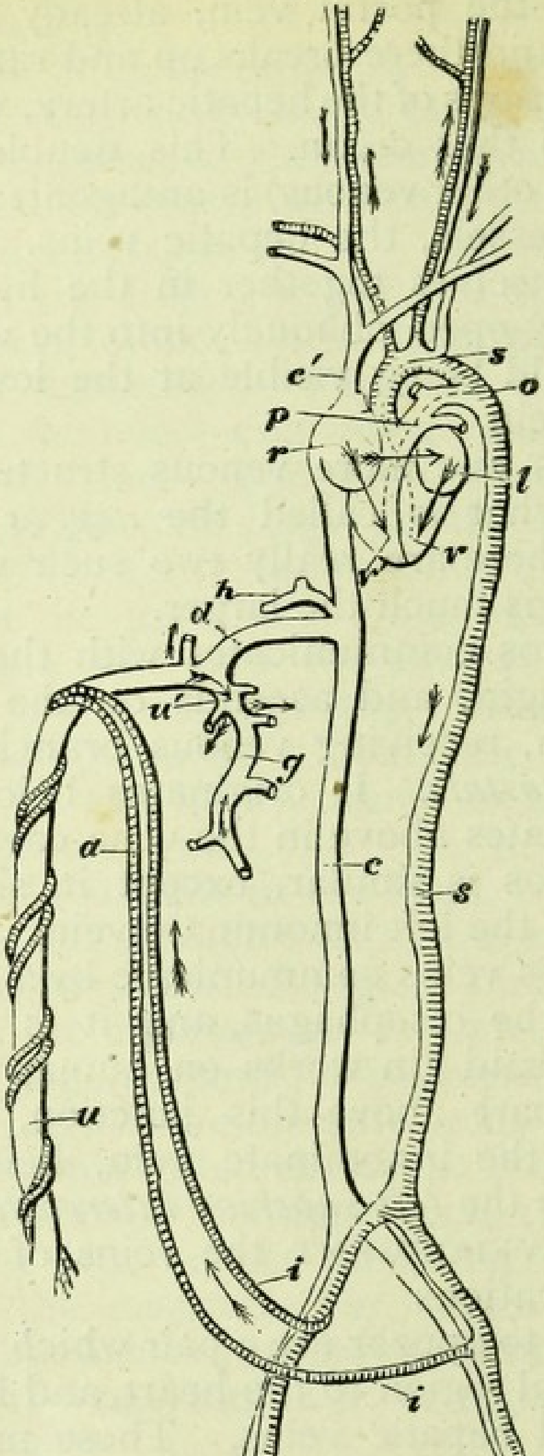

FIG. 367.—DIAGRAM REPRESENTING THE EARLY CONDITION OF THE CIRCULATION IN MAN.

The course of the blood is indicated by arrows.

(*After Quain and Sharpey.*)

s,s, the aortic arch and descending aorta ; *i,i,* hypogastric or umbilical arteries, afterwards forming the trunk of the internal iliacs, arising from the common iliacs ; *a,* the same arteries ascending to the navel ; *u,* umbilical vein ; *d,* ductus venosus going direct to the inferior vena cava ; *g,* vena portæ, returning blood from digestive organs ; *h,* hepatic veins ; *c,* vena cava inferior ; *c′*, vena cava superior ; *r,* right auricle ; *v′*, right ventricle ; *l,* left auricle ; *v,* left ventricle ; *p,* pulmonary artery ; *o,* ductus arteriosus.

meseraic veins, but also sends a branch directly to the sinus venosus.

Then the combined omphalo-meseraic and umbilical veins break up into the portal circulation—the branch direct from the latter to the sinus remaining however for a time as the *ductus venosus*. The part of the omphalo-meseraic vein near the heart which persists undivided thus, becomes the hepatic vein.

In the meantime the vena cava inferior arises as a large median vein (superficial to the aorta), receiving accessions from the pelvic limbs and from the kidneys. It intrudes, as it were, upon the hepatic veins, and gives its name to the vein directly entering the heart, into which the hepatic vein is described as opening in the adult.

After a time the posterior cardinal veins become discontinuous with the anterior ones, and grow into and become the azygos veins.

The anterior cardinal veins become the jugular and innominate veins. The left ductus Cuvieri aborts, and the left anterior cardinal vein proceeds to join the right ductus Cuvieri; the united trunk is thus transformed into the vena cava superior.

While the sinus venosus becomes indistinguishably united with the right auricle, the ductus venosus becomes obliterated, so that all the blood from the stomach and intestines passes into the portal circulation on its way to the heart. In the meantime the umbilical vein (which is, as it were, the root of the portal and primitive hepatic veins) in part aborts, becoming mere fibrous cord; in part, however, it persists, namely as the small internal iliac vein.

Concomitantly the vena cava inferior greatly increases in relative size, as also do its roots—the external iliacs. No veins are, on their way to the heart, re-distributed in the kidneys in the same way that the portal vein is in the liver.

10. Turning now to the general condition of the venous system, we find that the main conditions existing in adult man are those of his class, but that there may be certain variations as to the union of the larger trunks, and also as regards the presence of *venous retia mirabilia*—similar to those already noticed with respect to the arterial portion of the circulating system.

These *retia* seem to attain their maximum in the abdominal region of Cetaceans, *e.g.* the Porpoise. The two azygos veins may be much more equal in size than in man, as in the Monotremes. Instead of a single superior cava there may be two, the blood from the right and left sides of the head and pectoral limbs being gathered by two entirely distinct sets of vessels, each set ending respectively in a right and in a left vena cava, the two venæ cavæ each opening by a distinct aperture into the right auricle. This is the case in very many Mammals, *e.g.* in the Rabbit. The middle sacral vein of course increases in importance with the increase of the coccygeal region—being thus very large in the Cetacea.

Below man's class, and that of Birds, the blood from the caudal region and the pelvic limbs may enter the kidneys and be therein re-distributed by ramifying branches, similar to the re-distribution of the blood by the portal circulation in the liver. This is the case, *e.g.*, in Batrachians. Here, however, part of the blood from these sources is carried on, by *abdominal veins*, directly to the liver. But these veins may go directly to the vena cava inferior, as in Birds.

The great veins, before entering the heart, may dilate into a rhythmically contractile *sinus venosus*, as in most Batrachians and Reptiles.

The blood of the body may be brought back by cardinal veins and hepatic veins exclusively, as is the case in Fishes. These cardinal veins consist, on each side of the body, of an anterior one receding from the head and a posterior one advancing from the tail—the anterior and posterior cardinal vein of each side uniting to form a venous trunk (the ductus Cuvieri) which descends from the point at which these join, to the sinus venosus of the heart; thus exactly reproducing the primitive condition of man's venous system.

The portal vein itself may be rhythmically contractile, as in *Myxine* and *Amphioxus;* or the caudal vein may possess a pair of small contractile vesicles, as in the Eel. The root veins of the limbs may be contractile, as in many Batrachians, or veins so remote from the centre of the circulation as those which traverse the wing membranes of Bats may be similarly contractile.

Finally, as in *Amphioxus*, we may find many veins to be possessed of this property.

The veins may be destitute of valves, even in man's own class, as *e.g.* in the Cetacea.

11. We see, then, that not only structurally, but also physiologically, the circulating system, even in man's own sub-kingdom, may present very important divergences from the conditions we find in him.

Thus the blood, instead of being propelled in a double circuit as in man, may, as in Fishes and young Batrachians, make but a single great circuit, not returning to the heart till the whole round has been completed.

In this case the heart propels venous, unaërated blood only, which, quitting that organ by the bulbus aortæ, passes to the gills, where it undergoes aëration, not by decomposition of the water and extraction of its oxygen, but by the reception of that gas from the particles of air mechanically mixed up with the water which the creature inhabits. Having been thus oxygenated, the blood passes to the great dorsal descending aorta, and is thence distributed over the body.

Again, more or less blood may return to the heart before being distributed to the body generally, and thus there may be two circulations, as in man, and in all air-breathing Vertebrates.

In many animals which possess this double circulation, both venous and arterial blood may be more or less mixed up in the heart itself, and thus an impure fluid may be propelled by the aortic arches. This condition exists in all Batrachians and Reptiles, except the Crocodiles, though (owing to complex conditions with regard to the valves of the chambers of the heart and of the aorta) the mixture is much less complete than might be supposed, the blood from the lungs being almost entirely forced into that aortic arch which distributes its contents to the anterior region of the body. This is the case even in so low an animal as the common Frog.

The two states of blood may be as strictly divided between the two sides of the heart as in man, and yet a certain impurity in the circulation may exist. This is so in Crocodiles, where the two aortic arches, coming respectively from the venous and arterial sides of the heart, communicate.

That subordinate sub-division of the larger (or systemic) circulation which is called the portal system may, as we have seen, receive blood from more extensive sources than in man; and it may be, as we have also seen, not the only secondary circulation of the kind—for another like it may at the same time exist in each kidney, as is notably the case in Batrachians.

Rhythmical contractility, instead of being confined to the heart, as in man, may be widely distributed, as in the Lancelet; and this is especially the case with regard to the proximal ends of the main arteries and veins, which may be dilated respectively (as we have seen) into a *bulbus arteriosus*

(Figs. 356 and 362) and a *sinus venosus*, forming as it were two supplementary cavities to the heart. Even in man's own class, parts so remote from the heart as the veins adjacent to the fingers may become rhythmically contractile under special circumstances, as we have seen with regard to the Bat's wing.

The connexion between the systemic and pulmonary circulation takes place in all higher Vertebrates, as in man, *i.e.* only in the heart—its confusion in lower forms has just been mentioned.

The connexion between the blood carried to the gills and that which finds its way to the dorsal aorta may, as in most Fishes (*e.g.* the Perch), take place only by the capillaries of

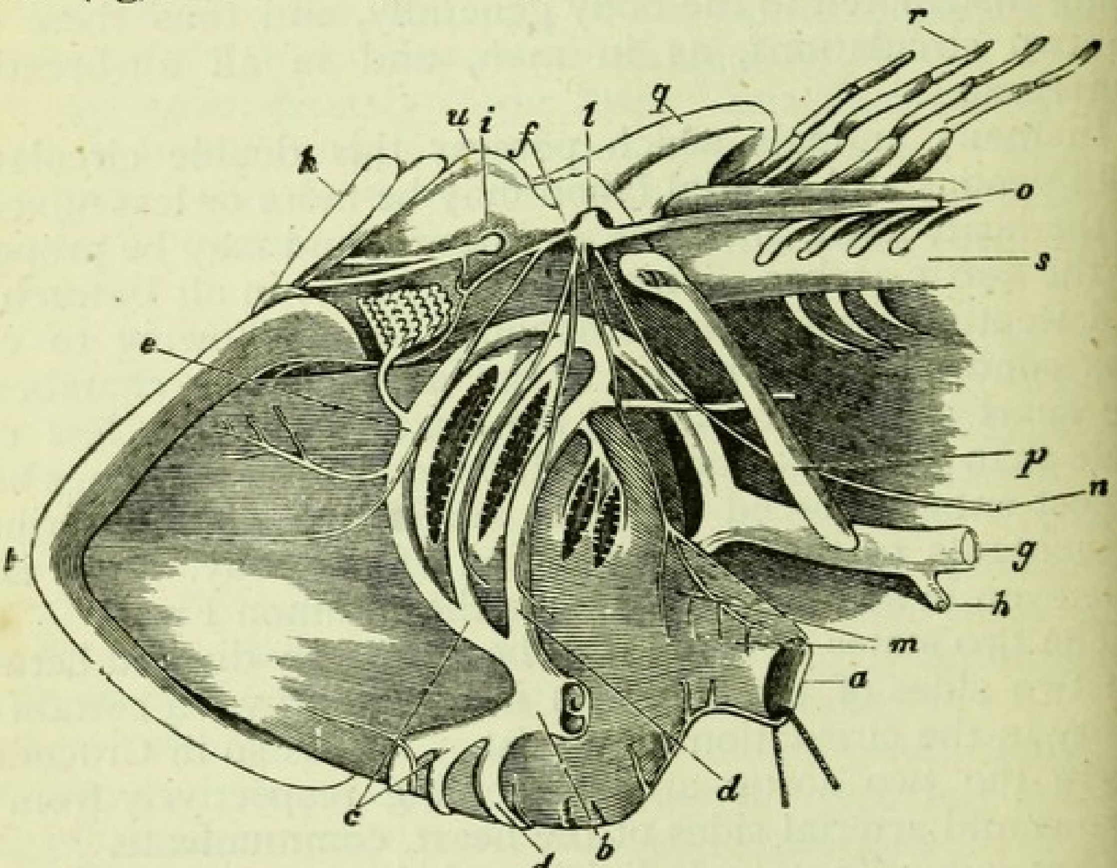

FIG. 368.—INFERO-LATERAL VIEW OF HEAD AND AORTIC ARCHES OF LEPIDOSIREN.

(*After Hyrtl.*)

a, œsophagus ; *b*, anterior end of bulbus aortæ , *c*, common roots of the first aort arches ; *d*, third aortic arch ; *e*, first aortic arch ; *f*, dorsal union of the thr first aortic arches ; *g*, aorta ; *h*, cæliac artery ; *i*, exit of the fifth nerve ; part of operculum ; *l*, exit of the nervus vagus from the skull ; *m*, branches œsophagus ; *n*, nerve going to the rectus abdominis ; *o*, nervus lateralis ; first and hypertrophied rib ; *q*, posterior part of skull ; *r*, segmented neu spines ; *s*, chorda dorsalis ; *t*, mandible ; *u*, quadrate.

the gills.[1] But, on the contrary, the vessels taking t blood from the heart to the gills may be connected

[1] For details of the circulation in the gills see p. 479, Fig. 405.

anastomosing branches with those which take the blood from the gills to the aorta. This we have seen to be the case in the Tadpole at a certain stage of its development. Indeed, the primitive condition in Fishes is that of a complete continuity of each arch from the heart to the dorsal aorta, and it is only as embryonic development proceeds, that each arch becomes broken up into a network of capillaries. Examples are not wanting of the persistence of this primitive condition throughout life in some of the arches, as *e.g.* in *Monopterus* and *Lepidosiren* (Fig. 368).

Thus we see that two different and divergent modes of respiratory circulation may be developed from the same starting-point: the primitive series of aortic arches in the one case sending out posteriorly extending branches for a lung-circulation; in the other case, themselves breaking up to form a gill-circulation.

A third mode of respiratory circulation, that by the skin, may supplement the others—as in Batrachians, where a large artery is given off from the heart to the cutis. As we shall see in Lesson XII., both pulmonary and gill respiration may co-exist, as in certain Tailed-Batrachians.

In man the heart is placed at a considerable distance from the cornua of the os hyoides, but in Fishes in close proximity to their enlarged representatives—the branchial arches.

At first, however, even in him, these parts are adjoined, and it is the subsequent displacement of the heart which causes certain diverging and obscuring structural conditions.

Thus the great aortic arch of Mammals is the remnant of the vascular arches going to the fourth embryonic visceral skeletal[1] arch, *i.e.* to the third behind the mandibular skeletal arch. Yet the thyroid artery is placed much in front of (*i.e.* preaxial to) the great aorta, though from the distribution of the thyroid artery it probably corresponds with an artery going to the fifth visceral skeletal arch, *i.e.* the third branchial arch of Fishes, and perhaps to the fourth and fifth also.

A similar explanation may be given of the fact noticed in the last lesson—the bending back of a nerve to the larynx called the *recurrent laryngeal.* This nerve originally passed behind the fourth aortic arch (one side of which persists as the great arch of the aorta), without any marked curvature. In the adult this nerve descends a long distance and then returns upwards at a sharp angle, passing on the left side round the arch of the aorta, and on the right side round the subclavian.

[1] For a description of these visceral skeletal arches see pages 95 and 143.

It has become, as it were, pulled out by the gradual displacement downwards of the heart and its arches from what was their primitive position. Its two ends in the meantime retaining their primitive connexions, the whole nerve becomes sharply bent, or "recurrent."

12. The supplementary part of the circulating organs which goes by the name of the LYMPHATIC SYSTEM has been already described in the second chapter of Professor Huxley's work so often referred to, the "Elementary Physiology," §§ 5 and 6.

It will be well, however, here to recapitulate certain leading facts.

The lymphatic system consists of two sets of vessels (distinguished by their place of origin) termed *lacteals* and *lymphatics*. Both are connected with certain rounded structures termed LYMPHATIC GLANDS.

Each gland consists essentially of a network of finely divided lymphatic vessels, on and amongst which capillary blood-vessels ramify, the whole being compacted together and surrounded by fibrous tissue.

The central part of the lymphatic system consists of a vertical canal, which ascends in front of the vertebral column and is called the *thoracic duct*. At its lower end (at the junction of the lumbar and dorsal regions) it is dilated into what is called the *receptaculum chyli*.

Into this duct all the lymphatics and lacteals ultimately empty themselves, except those of the right arm and right side of the head, which empty themselves into a small vessel called the *right lymphatic duct*.

Both these ducts open into the corresponding innominate veins.

Lymphatic vessels are provided with valves like man's veins, and exist in all parts of the body; but in the brain they take the form of investing sheaths for the blood-vessels, which run enclosed in lymphatics as a gas-pipe might run inside a drain-pipe.

The lymphatic vessels have proper walls, but they originate in mere channels, left, as it were, between the other tissues, and thus whatever is cast loose must find its way into the lymphatics.

The *lacteals* are the *lymphatics* of the alimentary canal, and pass through numerous lymphatic glands which are placed in the membranes (mesenteries) which attach that canal to the spine.

The lacteals end in the lower part of the thoracic duct.

Lymphatic glands are scattered in various parts of the body, but those most readily observed in man are the glands in the arm-pit, the groin, and the sides of the neck.

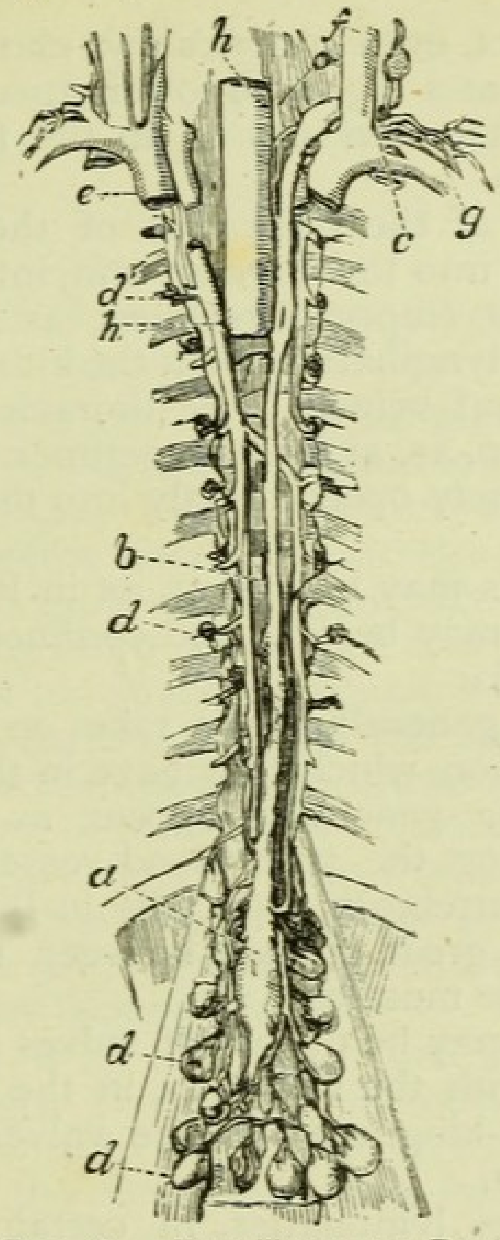

FIG. 369.—THE THORACIC DUCT.

The Thoracic Duct occupies the middle of the figure. It lies upon the spinal column, at the sides of which are seen portions of the ribs. At the bottom of the figure the psoas muscles appear.

a, the receptacle of the chyle ; *b*, the trunk of the thoracic duct, opening at *c* into the junction of the left jugular (*f*) and subclavian (*g*) veins as they unite into the left innominate vein ; *e*, the right innominate vein formed by the union of the left jugular and subclavian veins ; *d*, lymphatic glands placed in the lumbar and intercostal regions ; *h*, *h*, the cut œsophagus. Two veins are seen running alongside the lower part of the thoracic duct, and, just above its middle, one (the left) crosses under the duct and joins the other. These are the azygos veins.

No part of the lymphatic system of man is rhythmically contractile.

13. In surveying this system by the light furnished by the anatomy of other Vertebrates, we find that its condition may

be both more complex and that it may be the seat of more activity.

The right lymphatic duct may be so developed that there may properly be said to be two thoracic ducts, side by side, as in Birds.

The thoracic duct, even in man's own class, may be double, and may bifurcate at a higher or lower situation.

Again, the receptaculum may be in the form of a plexus, as in the Kangaroo.

The lymphatics of the right side of the head and neck may open directly into the jugular vein, into which vein the thoracic ducts also empty themselves, as in Birds ; and in the same class the lymphatics about the kidney open also into the renal and sacral veins. The thoracic duct may unite with the azygos vein, as, at least sometimes, in the Hog.

The lymphatics may open directly into the coccygeal vein, as in Fishes.

Lymphatic glands may be absent, as in Reptiles below the Crocodiles. They may be few, and confined to the region of the neck, as in Birds.

The lymphatics generally may take on an exaggerated form of that condition which they have in the human brain ; that is, they may generally appear as large reservoirs (sinuses) surrounding the true blood-vessels. Such is the case in the lower Vertebrata, especially in Batrachians, where also they may form great sinuses between the skin and the flesh, or between the muscles.

The lymphatics may be devoid of valves (which exist only at their junction with the veins), as in the lower classes of the Vertebrate sub-kingdom ; or the valves may be few in number, as in Birds.

The walls of the lymphatics, in certain localities, may become muscular and rhythmically contractile. Such pulsatile structures are called *lymphatic hearts.* There may be four of these structures, as in the Frog, where two such organs pump the contained fluid into small veins communicating with the subclavian veins at the shoulder, while two others, placed at the coccyx, send their contents into the crural vein.

Two dilated lymphatic structures, answering to the hinder lymphatic hearts of the Frog, may exist, as in some Reptiles, and also in Birds, *e.g.* the Goose, Ostrich, and others. In these classes, however, they are not rhythmically contractile pulsating structures, though even in Birds they contain striated muscular fibres.

LESSON XI.

THE ALIMENTARY SYSTEM.

1. THE ALIMENTARY SYSTEM of man has been in great part described in the Sixth Lesson of "Elementary Physiology," §§ 13—22. Here, however, a certain amount of recapitulation seems necessary for clearness.

This system begins, as all know, at the mouth, which is furnished with lips and a tongue, and which opens behind into the swallow (or pharynx), which, by means of the gullet (or œsophagus), leads down into the stomach, from which a long and very tortuous canal (the intestine) continues onwards to the termination of the alimentary tube or cavity.

The alimentary tube, from the lips downwards, has various fluids poured into it in different parts of its course, and these fluids are secreted (*i.e.* extracted from the blood) by certain organs termed glands.

Thus spittle is poured into the mouth by "salivary glands." "Gastric glands" supply their secretion, the gastric juice, to the stomach. A second set of spittle glands, the pancreas, pour the fluid they form into the intestine; and that vast organ, the liver, also pours into the alimentary canal its special formation, the bile. As has been already said, peculiar lymphatic vessels — the lacteals — collect nutritive fluid from the alimentary canal and convey it into the blood.

All the alimentary organs below the diaphragm—namely the stomach, intestines, liver, and pancreas—are invested by a fold of delicate serous membrane, which also lines the inner wall of the whole abdominal cavity, thus forming a very large sac, folded in an exceedingly complex manner and containing a serous fluid. This complex serous sac, by which the viscera are attached (as in a sling) to the front wall of the vertebral column, is called the *peritoneum*.

2. The MOUTH of man has been described in § 13 of the

Sixth Lesson of "Elementary Physiology," and its bony framework in the Third Lesson of the present course. It is bounded externally by fleshy and movable lips; while behind, a transverse fold of skin and muscle (called the soft

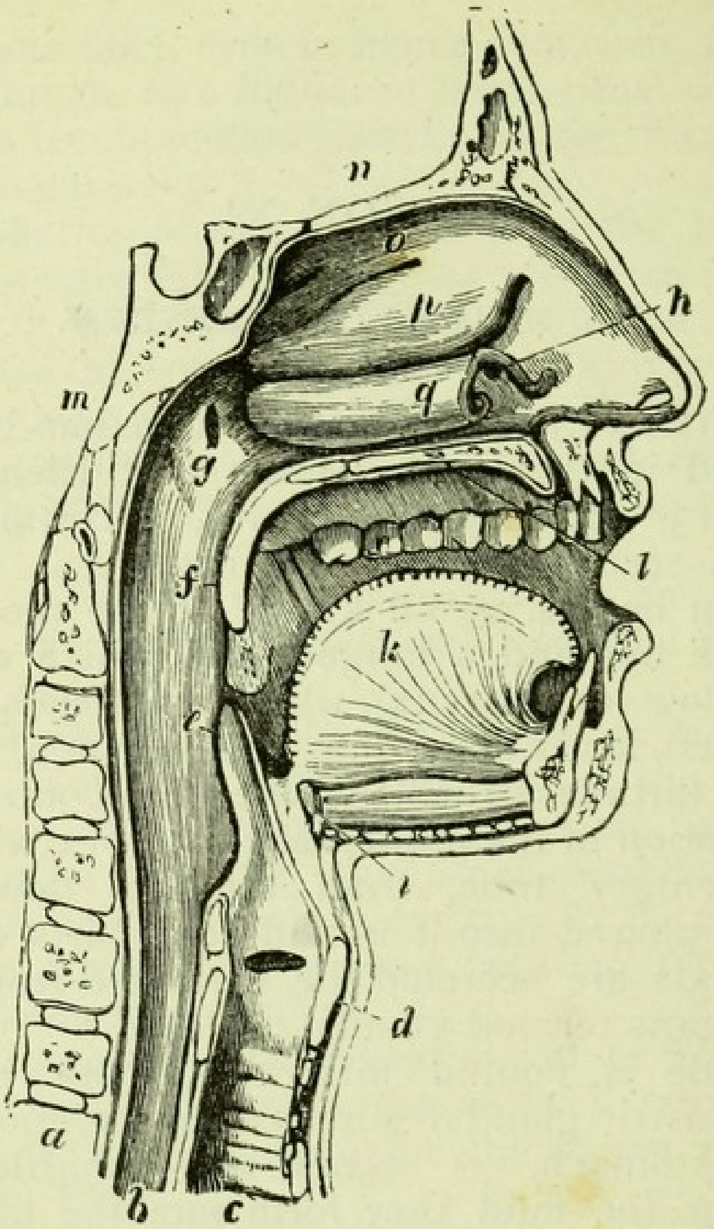

FIG. 370.—A SECTION OF THE MOUTH AND NOSE, taken vertically a little to the left of the middle line.

a, the vertebral column; *b*, the gullet; *c*, the windpipe; *d*, the thyroid cartilage of the larynx; *e*, the epiglottis; *f*, the uvula; *g*, the opening of the left Eustachian tube; *h*, the opening of the left lachrymal duct; *i*, the hyoid bone; *k*, the tongue; *l*, the hard palate; *m*, *n*, the base of the skull; *o*, *p*, *q*, the superior, middle, and inferior turbinal bones. The letters *g*, *f*, *e*, are placed in the pharynx.

palate, or *velum*) hangs down, from the middle of which a prolongation called the *uvula* depends. Behind this transversely extended curtain is situate the posterior aperture of the nostrils, which thus open, not into the mouth proper, but into the pharynx.

The Eustachian tubes also open into the pharynx above, while the aperture of the windpipe is situated below—behind the tongue (Fig. 370, *g*).

The teeth have been already noticed in the Seventh Lesson of this course.

On each side, the mouth is bounded by a fleshy cheek, only slightly distensible.

3. In reviewing the mouth as it exists in Vertebrates generally, we find that it may be entirely destitute of lips, as in Birds and Reptiles. These structures are not, however, confined to man's class, as they exist in some Fishes, *e.g.* the Carp and Dory. Nevertheless, lips are mainly mammalian structures, and may attain a much greater development than in man. Thus, in the Right-Whales the lower lip is an enormous structure, rising up on each side and overlapping the slit-like fissures which separate the numerous baleen plates before described.

The lips may be much more extensible than in man, as in even so nearly an allied form as the Orang. The upper lip may unite with the nose to form an elongated proboscis, as in the Elephant. It may be medianly divided by a vertical separation, as in the Rabbit, the Cat, or the Camel; and each lip on each side may send a process inwards, behind the incisors, as in the Rat. Lips, by rare exceptions, may be absent even in man's own class, as *e.g.* in the Ornithorhynchus, and they are scarcely developed in the Dolphins. An exceptional condition is seen in the Sturgeon, where an exceedingly small mouth opens on the under surface of the head, its lips being protrusible less by their own structure than by the singularly elongated and relatively large suspensorial apparatus before noticed.

In the Marsipobranchs we find a great circular lip, destined for suction and supported by complex special cartilages; and finally, in the Lancelet we meet with an altogether exceptional structure, namely, a mouth in the form of a vertical fissure, and provided on each side with a series of long, slender, pointed and ciliated[1] tentacles.

Sensitive tentacles, numerous and of small size, may border the lip, as in the Lamprey; or the lip may send out six or eight long tentacles, as in the Myxinoids. Higher Fishes may—as in the Mullets and Siluroids—have fleshy and sensitive labial barbs, or cirri.

A soft palate is a structure peculiar to man's own class, with

[1] Ciliated structures are such as bear *cilia*, or minute filaments which keep up an incessant waving motion. (See "Elementary Physiology," Lesson VII. § 3.)

the single exception of the Crocodiles, in which a transverse fold, or soft palate, hangs down in front of the posterior nares. A distinct uvula is only found in certain members of man's own order. The soft palate, however, may attain a greater development than it does in man, as *e.g.* in the Cetacea, where it is changed into a muscular canal, which prolongs the posterior nares, downwards and backwards. We may find, as in the Camel, a second and very long transverse process hanging down from the palate, just in front of the true velum. It ordinarily hangs down the throat, but in males at the rutting season is protruded from the mouth in a singular and conspicuous manner.

The soft palate may extend eight inches beyond the hard palate, and indeed half-way down the neck, as in the Ant-eater.

The hard palate, instead of only having very slight transverse prominences, as in man, may have them produced into strongly projecting ridges, as in the Pig, or into transverse rows of conical horny spines, as in the *Echidna*, or into great depending and dentated ridges, as in the Giraffe—a greater extension of a similar structure constitutes the baleen-bearing ridges of the Whalebone Whales.

The situation of the opening of the posterior nares has already been indicated in the Lesson on the Skull. The Eustachian tubes and teeth have also been already noticed.

The cheeks may be distensible, so as to form pockets, or "cheek-pouches," as in the Ornithorhynchus, some Rodents, and even in man's own order, as *e.g.* in the Baboons and the smaller and commoner Monkeys of Africa and Asia.

That median opening of the windpipe which exists in man, exists also in all air-breathing Vertebrates—even those which, like *Menobranchus*, have at the same time permanent gills. No such structure exists, however, in Fishes,[1] although in the Lamprey we meet with something analogous, as in that animal a canal conveying water to the gills opens at the back of the mouth, on the ventral aspect of the opening of the gullet. In the higher Fishes, instead of one such opening, several on each side serve (as we shall see in the Twelfth Lesson) to convey water from the alimentary tract to the respiratory organs.

4. The spittle, or SALIVARY, GLANDS of man are three in number :—(1) The *parotid* glands, one of which lies on each

[1] As to the ductus pneumaticus of the swim-bladder, see Lesson XII. § 3, p. 465.

side, in front of the ear, behind the ramus of the lower jaw, and in front of the mastoid process—resting on the styloid process and muscles. It gives off a tube, or duct, which runs forward outside the masseter muscle, and then turns inwards, piercing the buccinator muscle and cheek, so as to open into the mouth opposite the second upper premolar. (2) The *sub-maxillary* glands are next in size, and one on each side is placed within the lower part of the mandible and above the digastric muscle. Its duct runs forward and opens (close to its fellow of the opposite side) beside the fold of skin which attaches the under surface of the tongue to the floor of

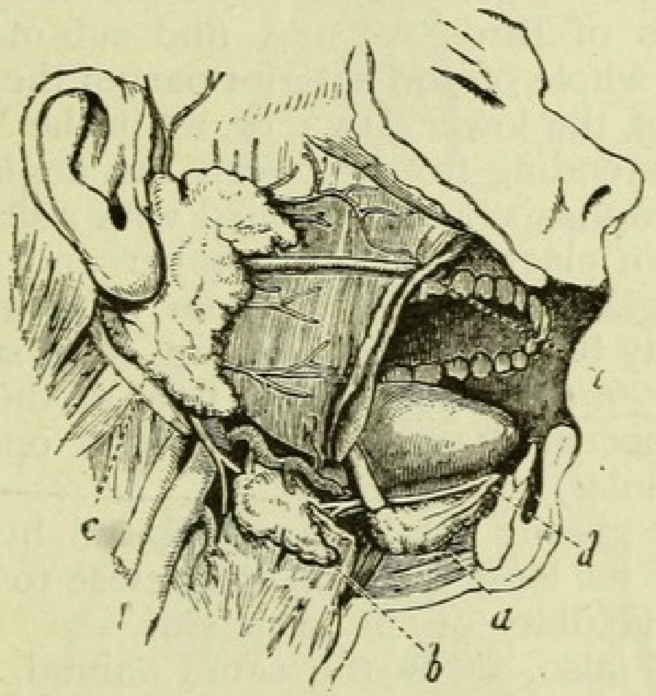

FIG. 371.—A DISSECTION OF THE RIGHT SIDE OF THE FACE.

a, the sublingual; *b*, the submaxillary glands, with their ducts opening beside the tongue in the floor of the mouth at *d*; *c*, the parotid gland and its duct, which opens on the side of the cheek at *e*.

the mouth. (3) The *sub-lingual* glands are still smaller, and are placed in the floor of the mouth, between the tongue and the gum of the lower jaw. They open by numerous minute ducts.

Besides these considerable structures, the mucous membrane which lines the mouth is beset with minute *buccal* glands.

5. On extending our view over man's sub-kingdom, we see that salivary glands may be entirely absent, as is the case in most Fishes, in Crocodiles, and in the Cetacea. Only in man's class do we find definite glands of all the three kinds above described, though very generally salivary glandular structures

exist in the tongue and in the inside of the skin investing the jaws, as in many Reptiles,—these latter structures answering to our buccal glands, as do also the salivary glands of harmless Serpents. Poisonous Serpents however are provided with an extra glandular structure, placed beneath and behind the orbit. This gland it is which secretes the venom, and its ducts convey the poisonous fluid to the base of the deeply-grooved poison fang described in the Seventh Lesson. By a very rare and remarkable exception, the poison gland may (as in *Callophis intestinalis*) attain enormous proportions, extending backwards as far as the heart, being lodged in the general cavity of the body.

In the class of Birds we may find sub-maxillary glands occupying the whole of the anterior part of the space included by the rami of the lower jaw; or, as in the Woodpecker, a single gland extending from between the angles of the mandible to its symphysis, and furnished with a distinct duct.

In man's own class, both the number and relative size of the salivary glands may differ from what we find in him. Thus there may be, as in the Dog, an extra structure, called the *zygomatic gland*, placed in the floor of the orbit, behind the anterior root of the zygoma (its duct opening opposite the last true molar), and also another, the *second*, or *accessory sub-maxillary* gland, smaller, and placed beneath the true sub-maxillary, its long duct opening close to the aperture of the true sub-maxillary of the same side.

The parotid also, as in the same animal, may be somewhat smaller in size than the sub-maxillary, but this disproportion is insignificant in comparison with that produced by the enormous development which the sub-maxillary glands sometimes acquire, as in the Ant-eaters, where these glands meet together and unite on the chest, superficially to the sternum. The sub-maxillary ducts may each be connected with a dilated vesicle, or salivary bladder, as in the Armadillos; or they may branch out and break up, opening by many minute orifices on the floor of the mouth, as in the Echidna; or each may remain single, but take a very tortuous course, as in the Ornithorhynchus. Parotid glands may be absent (the other salivary glands being present) in man's own class, as in the Monotremes.

6. Man's TONGUE is a muscular body connected with the os hyoides in the way already noticed in the Eighth Lesson. Its under surface is bound down by a fold of mucous membrane, called the *frænum*, which proceeds from the middle

line downwards, and then dividing, passes outwards to the gum on each side of the lower jaw.

Both on the right and left of this frænum is a little papilla, on which opens the duct of the sub-maxillary gland of the same side.

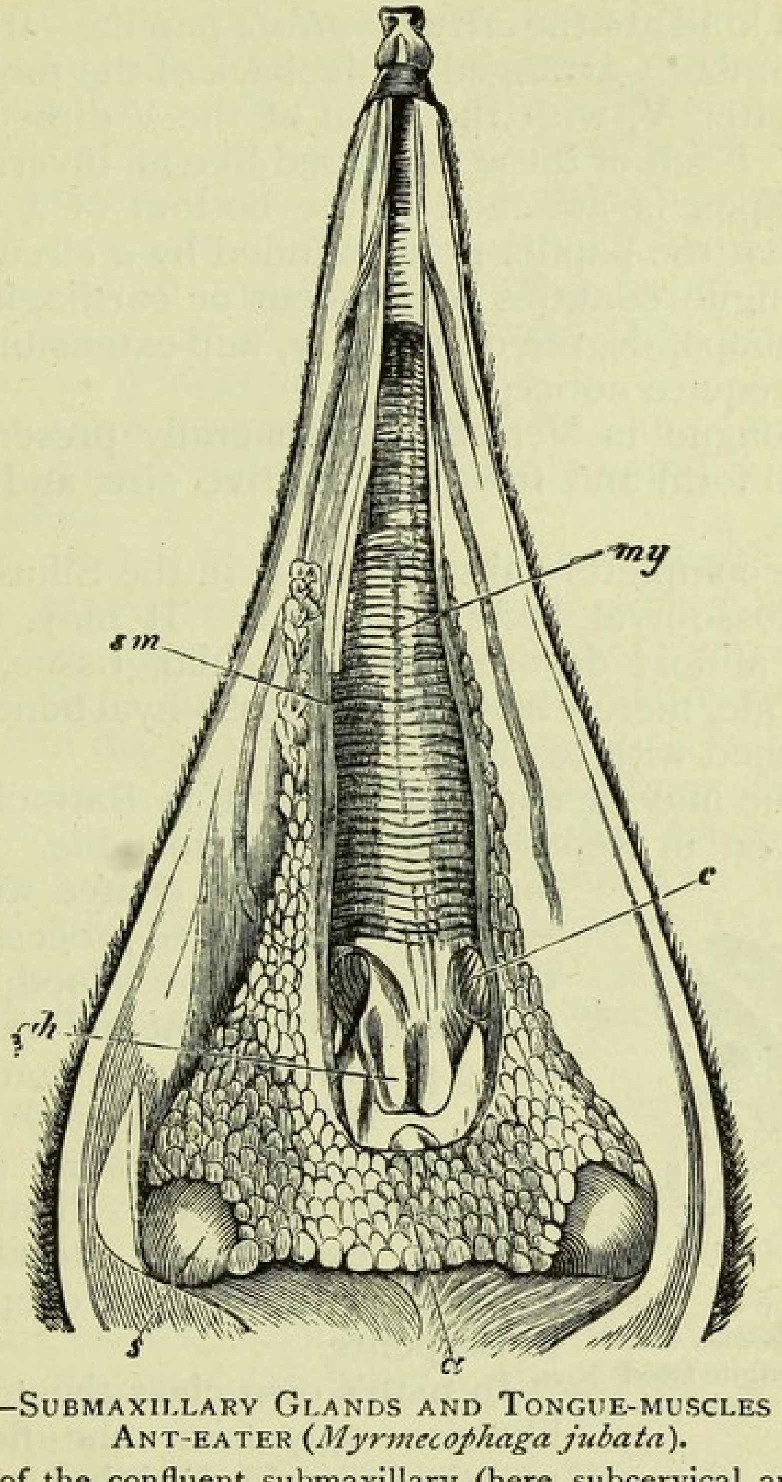

FIG. 372.—SUBMAXILLARY GLANDS AND TONGUE-MUSCLES OF GREAT ANT-EATER (*Myrmecophaga jubata*).

a, main body of the confluent submaxillary (here subcervical and subpectoral) salivary glands; *c*, dilated portion of duct (or salivary reservoir) surrounded by muscle; *gh*, genio-hyoideus; *my*, mylo-hyoideus; *s*, prominence of shoulder-joint; *sm*, sterno-maxillary muscle.

(*After Owen.*)

On the upper surface, or *dorsum*, of the tongue, are three kinds of small prominences, or papillæ. Towards the front end they are mostly long and pointed, and are called *conical* and filiform papillæ.

Scattered over the middle of the tongue are very red papillæ, called *fungiform*, because each is narrower at its root than at its upper part.

The third kind are the *circumvallate* papillæ—from eight to fifteen in number—arranged at the back of the tongue so as to form the letter V, with the point of the V directed towards the throat. Each of these is shaped like an inverted cone, of which the apex is attached to the bottom of a cup-shaped cavity, so that the papilla is surrounded by a circular furrow.

Man's tongue contains no osseous or cartilaginous structure. Its shape, degree of mobility, and extensibility are too familiar to require notice.

7. The tongue in Vertebrates generally presents a great variety as to form and function, relative size, and denseness of structure.

It may be completely absent, as *e.g.* in the Siluroids, where even the glosso-hyal bone is absent. It may, as in most Fishes, be almost destitute of muscular tissue, and very slightly mobile, merely investing a glosso-hyal bone, and often being furnished with teeth.

The tongue may be apparently absent in Batrachians, as in *Pipa;* or even in Reptiles, as in the Crocodile. It may be long, pointed, and coated with a horny sheath, with recurved processes towards the apex, as in the Woodpecker. It may be fixed in front and free behind—being protruded by eversion—as in the Frog. It may be very extensible, thickened and somewhat cup-shaped at the end, as in the Chameleon. It may be exceedingly mobile and extensible, with its apex deeply cleft, as in Serpents.

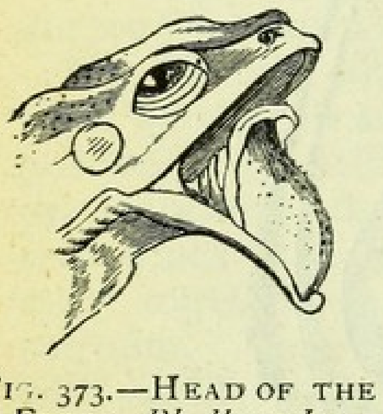

FIG. 373.—HEAD OF THE FROG *Phyllomedusa*, showing the tongue fixed in front, but free posteriorly.

In man's own class the tongue may likewise only form the floor of the mouth, as in the Dolphin. It may, as in the Dog and Mole, have on its under surface a longitudinal fusiform, rather dense body, attached to the rest by cellular tissue, and called the worm, or *lytta*. The conical papillæ may be horny, and shaped like small claws, as in the Cat. Fungiform papillæ may be absent, as in the Horse and Manatee. There may be but two circumvallate papillæ, as in the Rabbit and *Proteles;* or but one, as in the Rat and Pig. They may be disposed in two parallel lines, as in the Sheep; or altogether absent, as in the Manatee. They may be, as in the Orang, arranged in the same way that they are in Man; or they may form the letter Y or T, as in the Chimpanzee. There may be a large horny papilla on each side, as in Manatee and Ornithorhynchus; or there may be horny plates on the tongue, as in the Java Porcupine.

The tongue may be extraordinarily smooth, but with little mobility and flexibility, as in the Elephant; or small, narrow, and tied down, as in the Manatee. It may have a bifurcating apex, as in the Seal. It may be enormous, yet attached all round nearly to the very tip, and without papillæ, as in the Whalebone Whale.

The tongue may be exceedingly long, and furnished all round, except at the tip, with backwardly pointing spines, as in the Tamandua.

This organ attains its greatest relative length amongst Mammals in *Manis*, where its muscles extend backwards, taking origin in the very elongated xiphoid process of the sternum. There is also a sterno-glossal muscle in the Great Ant-eater and in the Echidna.

There may be a considerable cartilaginous lamelliform process extending forwards beneath the tongue, taking origin from its under surface further back, and having the appearance of a second small tongue beneath the true one. Such a structure is found in Lemurs. It is independent of the papillæ for the sub-maxillary ducts, which papillæ are at the same time conspicuous.

These latter may unite to form a little bifid body beneath the tongue, as in the Gibbons.

The papillæ on which the sub-maxillary ducts open may be more elongated than in man: such is the case even in the Chimpanzee.

8. The ŒSOPHAGUS, or gullet, of man is a nearly straight membranous and muscular tube, leading from the pharynx to the stomach.

It consists externally of longitudinal and also of circular muscular fibres. Within this muscular coat there is cellular tissue, and this again is lined with mucous membrane.

The STOMACH is formed of similar materials, and has been sufficiently described in the Sixth Lesson of "Elementary Physiology," § 18. It is a simple, somewhat pear-shaped bag, curved, so that its upper surface is concave. The gullet opens near the wide left end, or *fundus* of the stomach, which part is called its *cardiac* part. The opposite end, or *pylorus*, leads into the intestine—the muscular fibres projecting, at the point of junction, so as to form a sort of valve.

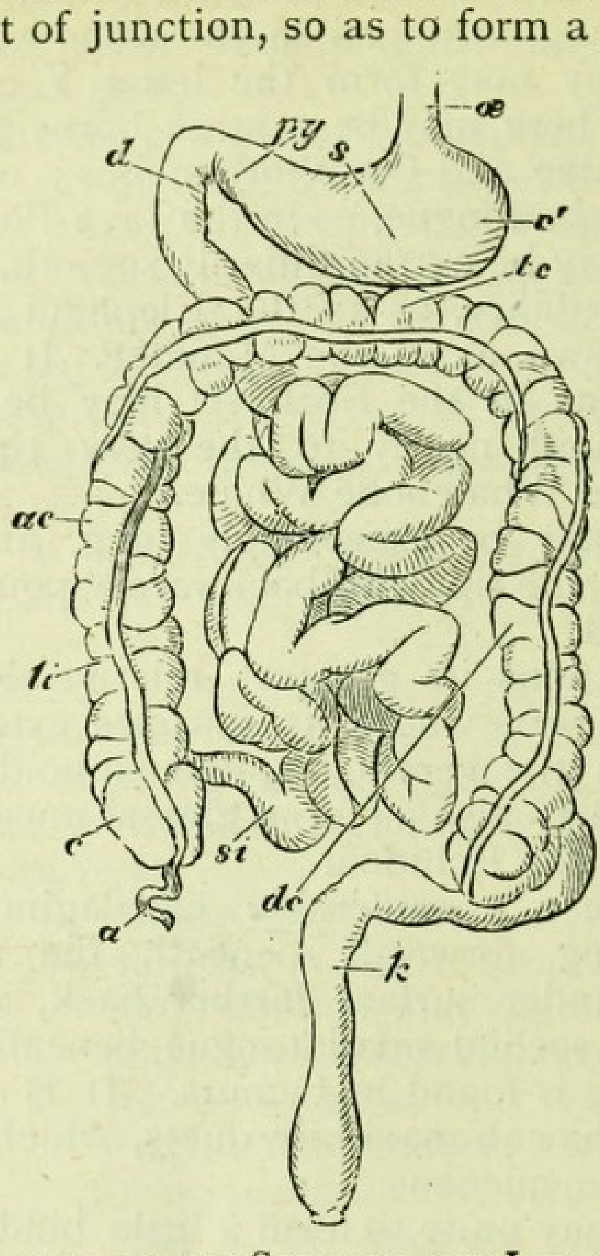

FIG. 374.—DIAGRAM OF THE STOMACH AND INTESTINES OF MAN.

a, vermiform appendix; *ac*, ascending colon; *c*, cæcum; *c'*, cardiac end of stomach; *d*, duodenum; *dc*, descending colon; *k*, rectum; *li*, large intestine (extending from *c* to *k*); *æ*, œsophagus; *py*, pyloric end of stomach; *s*, stomach; *si*, end of convoluted small intestines (which begin at *d*); *tc*, transverse colon.

9. On extending our view over Vertebrates generally, we see that the *œsophagus* may be very short and wide, as in most Fishes; also that it may be exceedingly distensible, as in Serpents.

It may be furnished with long, hard, conical papillæ, directed backwards, as in Chelonians.

It may have a special sac-like dilatation attached towards its lower part, as in most Birds (Fig. 378, *cp*), where this portion is called the *crop*, which may be double, as in Pigeons.

Nothing like a crop exists in man's class, with the single exception of the common Dormouse, which has the lower end of the œsophagus enlarged into a glandular dilatation.

The œsophagus may be much more muscular than in man; or it may be rather valvular at its lower end, as in the Dugong, and still more so as in the Porpoise.

The *stomach* is sometimes indistinguishable from the œsophagus, with which it is directly continuous, without any marked constriction, as in most Fishes. It may form one continuous canal with the œsophagus, even in Birds, *e.g.* the Cormorant; and indeed in Birds (Fig. 378, *pr*), generally the first or cardiac part of the stomach (called the *proventriculus*) seems to resemble more a dilatation of the lower end of the œsophagus—like that of the Dormouse—than a stomach proper.

It may attain to a very much greater complexity than it attains in man, as we see by the Sheep.

The various exaggerated forms which the stomach assumes may be arranged under two heads: (1) an elongation, (2) a differentiation, with distinct correlated chambers.

The first condition may exist even in man's own order, as in the long-tailed Monkeys of India, the *Semnopitheci*, which have the pyloric part of the stomach exceedingly elongated and also sacculated, *i.e.* puckered up into a successive series of bags. This condition is carried still further in the Kangaroo, where the cardiac end is also exceedingly prolonged.

The second form of stomach is slightly exemplified in the Pig, where the cardiac fundus is dilated into a little pouch,

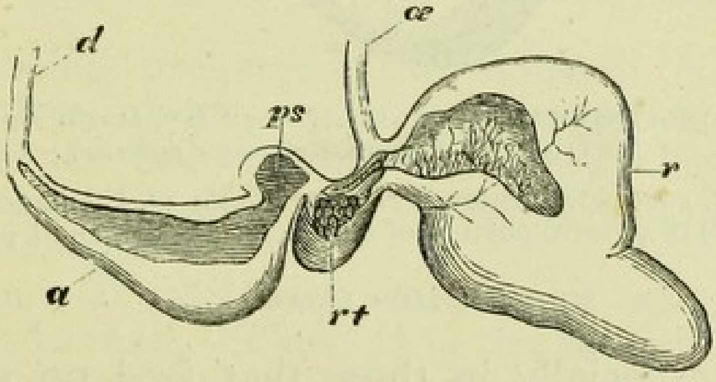

FIG. 375.—STOMACH OF A SHEEP, cut open to show the various lining of the different parts.

œ, œsophagus; *r*, rumen or paunch; *rt*, reticulum or honeycomb; *ps*, psalterium or manyplies; *a*, abomasum or rennet; *d*, duodenum.

while two parallel folds lead from the œsophagus to the pylorus. In the Sheep, however, we find the cardiac end dilated into an enormous paunch, while close to the œsophagus is a small chamber, called the *reticulum* (on account of the net-like appearance of the free margins of the honey-comb-shaped folds of its lining membrane). The rest of the stomach is divided into a small chamber, the *psalterium*, and a larger terminal portion, the *abomasum*. Two folds of membrane lead from the lower end of the œsophagus to the psalterium, and convey into it the food which descends after that second mastication (called *rumination*) by which the hastily swallowed grass, regurgitated from the paunch, undergoes the requisite degree of comminution.

Another complication of stomach is produced by an enormous increase of the muscular coat of the pylorus. A stomach so thickened is called a *gizzard*, and is found in

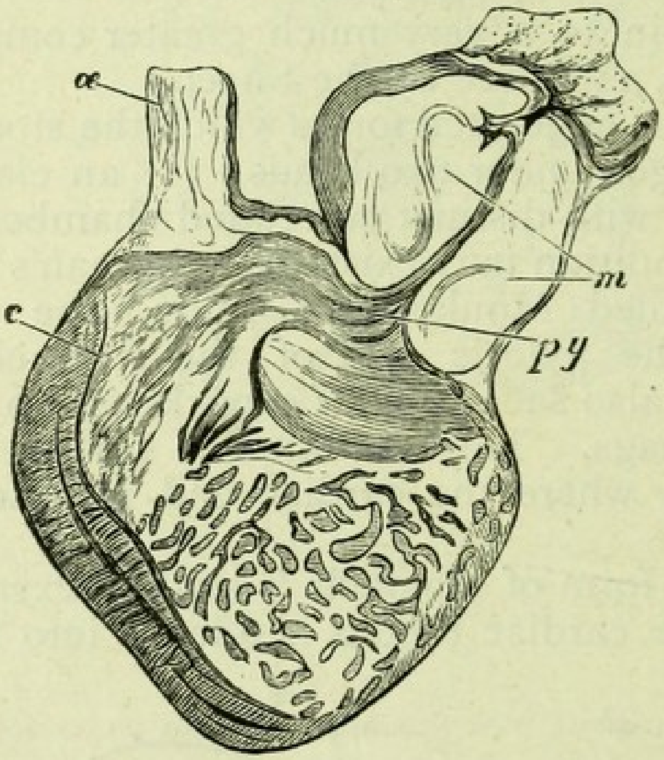

FIG. 376.—LONGITUDINAL SECTION OF THE STOMACH OF THE GREAT ANT-EATER (*Myrmecophaga jubata*).

œ, œsophagus; *c*, cardiac division of the stomach; *m*, thickened muscular walls (or "gizzard") of pyloric portion of stomach; *py*, orifice of pyloric division of stomach.

(*After Owen.*)

most Birds, especially in those that feed on grain, as the common Fowl. A gizzard may, however, be developed in man's own class, as *e.g.* in the Great Ant-eater.

Yet another form of complication is exemplified amongst Mammals by the Dugong, which animal has two long cæcal appendages attached to its stomach. Many cæcal appendages may coexist, as in Fishes, but these open into the commencement of the intestine, and not into the stomach proper (Figs. 381 and 382, *p*).

Another and an exceedingly exceptional condition of the stomach may exist, as *e.g.* in the blood-sucking Bat *Desmodus*. Here we have the cardiac end produced into an enormously prolonged pouch, while the pyloric part is reduced to a rudiment—the highly nutritious food (blood) requiring very little digestion, but needing a large chamber for its speedy reception.

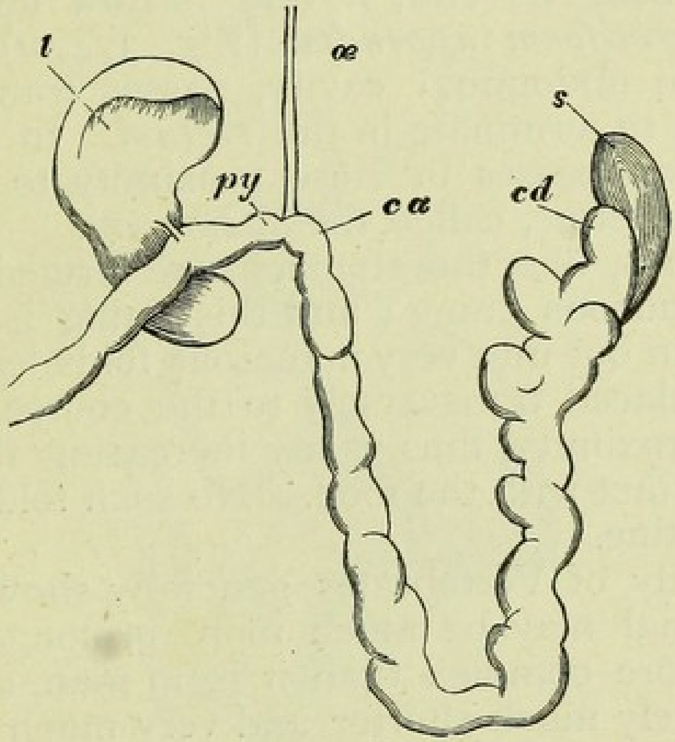

FIG. 377.—STOMACH AND ADJACENT VISCERA OF THE BAT *Desmodus*. (*After Huxley.*)

œ, œsophagus ; *ca*, cardiac part of the stomach enormously elongated to *cd*, the cardiac cæcum ; *py*, short pyloric part of the stomach ; *l*, liver ; *s*, spleen.

Instead of being prolonged, the stomach may be very much shorter than in man, and indeed its depth may exceed its length. as is the case in the Ornithorhynchus and some Insectivora, e.g. *Rhynchocyon*. It may also be globular, as in the Fish *Mormyrus*.

Special glandular structures may exist which have no representatives in man. Thus, as in the Rodent *Lophiomys*, there may be a glandular offshoot from the stomach—near the pylorus. Again, there may be (as in the Wombat and Beaver) a glandular mass within the stomach, situated between the œsophageal and pyloric apertures. Finally, there may be (as in the Dugong) a complex gland within the cardiac fundus, formed by a membrane which is spirally arranged below, but radiating above.

10. The INTESTINES of man have been described in the Sixth Lesson of "Elementary Physiology," §§ 21—23. It may be here mentioned that the long convoluted tube immediately proceeding from the pyloric end of the stomach is called the small intestine. This terminates by a definite opening (defended by a valve) into a much wider and sacculated tube, called the large intestine, or *colon* (Fig. 374, *ac*, *tc*, and *dc*). Near the point of junction, the end of the colon projects blindly in what is called the *cæcum*, which latter has attached to it, near its end, a very narrow hollow process, called the *vermiform appendix* (Fig. 374, *a*). The colon ascends in the abdominal cavity, passes transversely, and then descends to terminate in the *rectum*. In its transverse course the colon passes in close proximity to the first part of the small intestine, called the *duodenum*.

The intestines, like the stomach, are formed of muscular fibres with a mucous lining; and this lining is, in the small intestine, drawn out into very numerous folds (called *valvulæ conniventes*), placed transversely to the course of the bowel and in close proximity, thus vastly increasing the amount of surface in contact with the food. No such folds exist inside the large intestine.

11. The study of Vertebrates generally shows us that the alimentary canal may be much more prolonged relatively, and may be more complex than it is in man, as also that it may be relatively much shorter and very much simpler than in him.

In man the intestines are six or seven times the length of the body, but in his own class they may be as little as three times that length, or even less—as in Bats and Shrews; while they may be as much as twenty-seven times—as in the Sheep.

Passing beyond man's class, we find that the intestines may but little exceed the length of the body, as in many Lizards (Fig. 384) and Serpents, and may even fall short of it, as in some Fishes.

In that his intestine is divisible into "large" and "small," man agrees with the great majority of members of his sub-kingdom. Nevertheless, all distinctions between these parts may be wanting, so that the whole intestine forms one simple canal, as *e.g.* in the Carp, and still more strikingly in the Lamprey. Even in man's own class there may be no distinction in size between the large and small intestines, as in the Shrews—and there is hardly any in the Porpoise.

The proportion as to length borne by the small intestine to the large is generally in Mammals less than in man, in whom it is as five to one; but the large intestine may be very short (not more than a tenth the length of the body), as in most Birds; it may be, on the contrary, actually the longer portion of the intestine, as in the Ostrich.

The presence of a cæcum is not quite constant in man's class, and this structure is never found in Fishes, though it is often present in Reptiles, and generally in Birds. In Fishes,

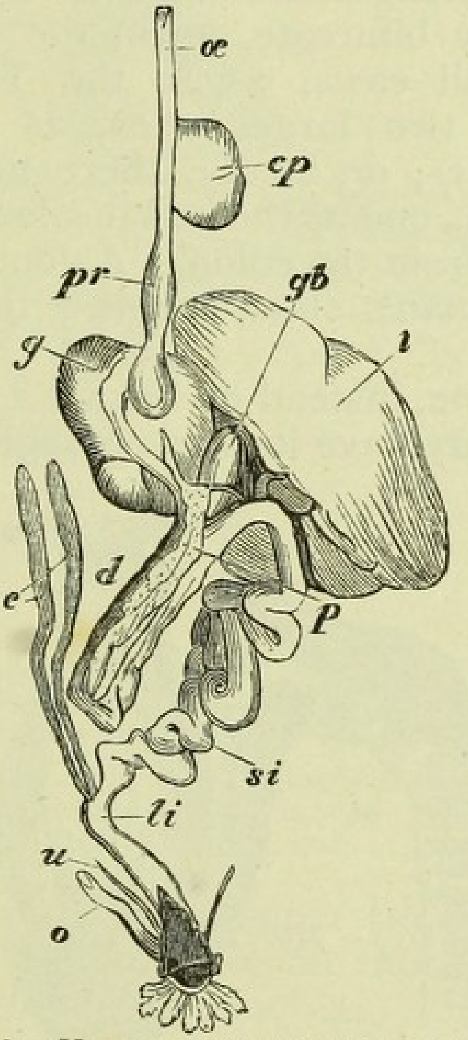

FIG. 378.—VISCERA OF THE COMMON FOWL.

oe, œsophagus; *cp*, crop; *pr*, proventriculus; *g*, gizzard; *l*, liver; *gb*, gall-bladder; *p*, pancreas; *d*, loop of the duodenum enclosing the pancreas; *si*, small intestine; *li*, large intestine; *e*, cæca; *o*, oviduct; *u*, ureter.—The cloaca is cut open and some feathers are represented attached to its margin.

indeed, there are often many cæcal appendages to the intestine, but these will be noticed below in describing the Pancreas.

In man's class the cæcum often presents an inverse degree of size and complexity compared with the stomach. It may be enormous, as in the Indris, the Hare, the Galeopithecus, the Koala, and the Horse. It may be very simple and short, as in the Opossum and others. It may be wanting altogether, as in the Hedgehog, Weasels, Porpoise, and others.

A vermiform appendix is very rarely found except in man. It exists, however, in the highest Apes and in the Wombat; while in the Monotremes there is a small worm-like cæcum which suggests the belief that this appendix in the Wombat is but an abruptly atrophied condition of the free end of the cæcum—a belief strengthened by the condition found amongst Lemuroids, which have a very long cæcum, drawn out into an elongated conical termination.

The cæcum may bifurcate, as in the Manatee; or there may be two small cæca, as in the Two-toed Ant-eater (*Cyclothorus*), or two larger ones, as in the Armadillo (*Dasypus sexcinctus*); or, finally, there may be—as in the Hyrax—three cæca, one at the usual situation, and two side by side projecting from the colon. A double cæcum is a very rare condition in man's class, but it is the rule in the class of Birds (Fig. 378, *e*).

The large intestine, instead of having a form and arrangement as in man, may have its various regions elongated and

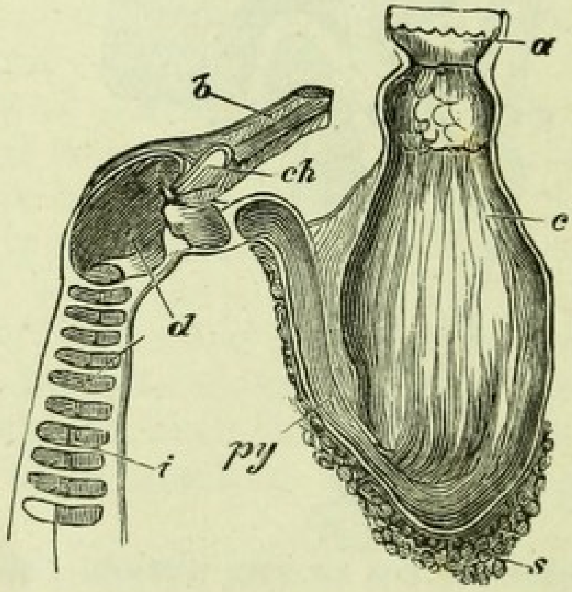

FIG. 379.—SECTION OF THE STOMACH AND PART OF THE INTESTINES OF A SHARK (*Squalus maximus*).

æ, œsophagus; *c*, cardiac part of the stomach; *py*, its pyloric part; *s*, the spleen; *d*, the duodenum; *b*, a band containing six hepatic ducts; *ch*, a dilatation in which these six ducts terminate; *i*, the intestine, provided with a spiral valve.

convoluted, or the whole greatly augmented in length and reduced in diameter, and coiled in a peculiar and characteristic manner, as *e.g.* in the Sheep.

Valvulæ conniventes, absent even in the species most allied to man, reappear in an exaggerated form in the small intestine of the lowest member of his class—the Ornithorhynchus. Folds of membrane may be so developed as to form a spiral valve within the intestine, as in Sharks.

12. The PANCREAS of man is a long, soft, narrow, flattened gland (larger at one end than the other), which lies embraced by a curve of the duodenum. Its excretory duct traverses its length and enters the duodenum a little below the pylorus,

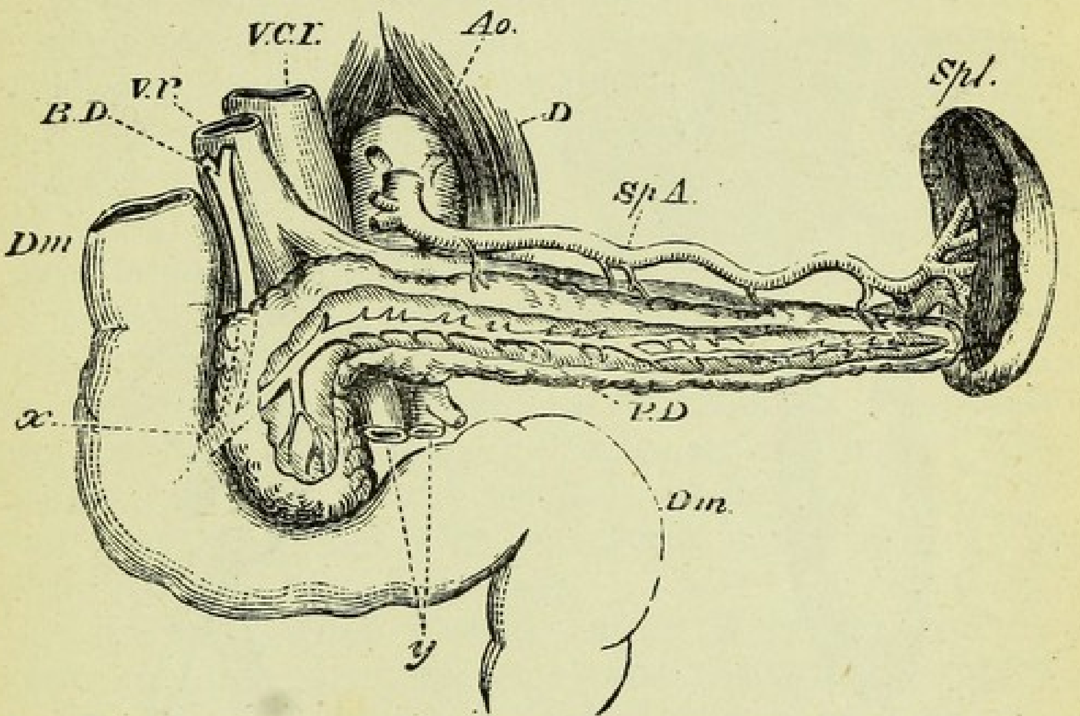

FIG. 380.—THE PANCREAS with its duct (*PD*), together with the spleen (*Spl.*) and the splenic artery (*SpA*). Below this artery is seen the splenic vein running to help to form the *vena portæ* (*VP*).

Ao, the aorta; *D*, a pillar of the diaphragm; *PD*, the pancreatic duct exposed by dissection in the substance of the pancreas; *Dm*, the duodenum; *BD*, the biliary duct opening into the pancreatic duct at *x*; *y*, the intestinal vessels.

receiving on its road the bile-duct (to be noticed below), so that the two open together into the intestine. The length of the gland is from six to eight inches.

13. The *pancreas* (or sweetbread) of other Mammals may be more developed and complex than in man, as in Bears, and may have two ducts—as generally in Dogs. It may present a beautiful arborescent structure, as in the Hedgehog and Flying Fox. It may be in the form of three long lobes meeting together, as in the Pig.

The duct may enter the intestine at a much greater distance from the pylorus than in man (as *e.g.* in the Beaver and Rabbit), and quite distinctly from the bile-duct.

In Birds the pancreas appears as a narrow elongated gland lodged in the fold of the duodenum, and generally bent upon itself like the gut it adjoins. It has usually two ducts entering the intestine in advance of the entrance of the biliary secretion.

An essential similarity exists in the pancreas, not only of Reptiles, but also of Batrachians; and yet in Fishes this organ appears to be replaced by quite another structure. In most bony Fishes there are several, or many, cæcal pouches attached to the commencement of the alimentary canal. These may be but two in number, as in the Turbot; or there

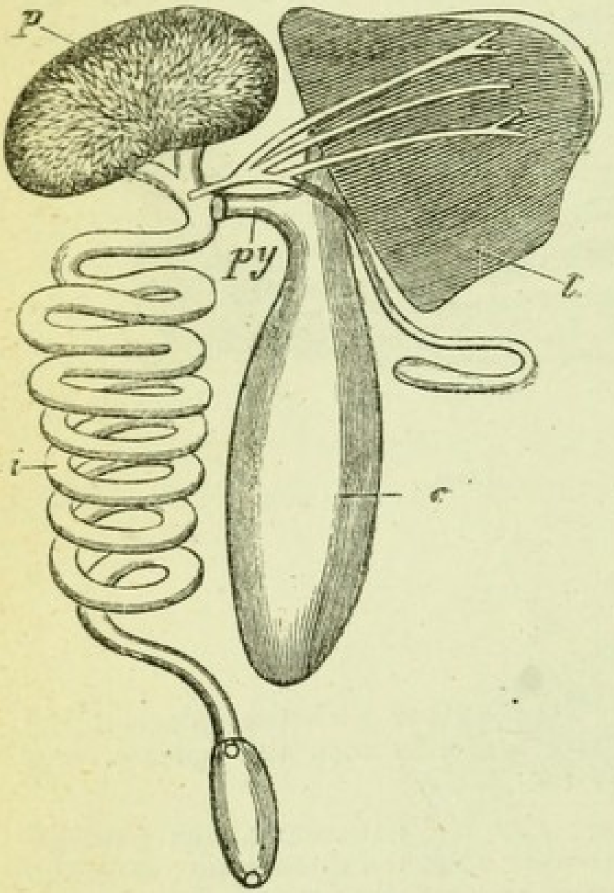

FIG. 381.—DIGESTIVE ORGANS OF A SWORD-FISH (*Xiphias gladius*).

l, liver; *c*, cardiac part of the stomach; *py*, its pyloric part; *p*, pyloric cæca massed into a body like the conglomerate pancreas of Mammals; *i*, intestine.

FIG. 382.—STOMACH AND INTESTINE OF A WHITING (*Merlangus vulgaris*).

(*After Hyde Salter.*)

œ, œsophagus; *c*, cardiac end of the stomach; *py*, pylorus; *p*, numerous pyloric cæca; *i*, intestine.

may be but a single tube, as in *Polypterus;* or fifty, as in the Pilchard; or about 120, as in the Whiting. They may be all distinct, or they may be agglomerated together into a sort of solid gland (showing a certain resemblance to the pancreas of higher animals), as in the Sword-fish. The pancreas may be altogether wanting, as in the Lancelet.

14. The LIVER of man, the largest gland in his body, has been noticed in the Fifth Lesson of "Elementary Physiology,"

It is placed rather to the right side of the body, immediately beneath the diaphragm and above the stomach, and lies within the cartilages of the ribs. The aorta, vena cava, and the crura of the diaphragm are interposed between it and the bodies of the vertebræ, whence it extends to the front of the abdominal cavity and to its right and left sides.

It is a solid organ, of a dull reddish-brown colour, smooth and convex above, concave and uneven below. It is divisible into certain parts (or *lobes*), which are defined partly by grooves and notches, partly by ligaments and blood-vessels.

In the Tenth Lesson of the present course was described how blood is conveyed to the liver from the viscera by the portal vein, and from the liver to the adjacent vena cava by the hepatic veins, while the nutritive blood from the aorta is distributed to the liver by the hepatic artery, itself a branch of the cœliac axis. It was also noted how in an early stage of development a stream of blood is conveyed by a temporary vessel, the umbilical vein, which in part joins the vena porta, in part sends small branches into the liver, and in part directly unites with the vena cava by a temporary canal called the ductus venosus.

Now the liver, when viewed above, is seen to be divisible into two unequal parts, one right and the other left, by means of a membranous ligament (called the *broad* or *falciform ligament*) which descends to it from the adjacent surface of the diaphragm and consists of two folds of peritoneum, as will be hereafter explained. This ligament is attached to the liver in a line running from the posterior margin of that organ to its anterior one, and the part of the liver on the left of the ligament is much smaller than that on its right.

Viewing the liver on its under surface (Fig. 383), there may be seen a deep groove opposite to and corresponding with the attachment of the broad ligament (called the *longitudinal fissure*), which lodges a fibrous cord (called the *round ligament*). The anterior part of this cord (which passes backwards to the liver from the navel) is the remnant of the primitive umbilical vein, while the posterior part is similarly a relic of the ductus venosus. On this account the anterior part of the longitudinal fissure is called the *umbilical fissure*, while its posterior part is named the *fissure* of the *ductus venosus* (Fig. 385).

This longitudinal fissure then divides the liver into two unequal lobes on its under surface, and the larger of these lobes is again subdivided by other fissures. Thus a small prominent lobe (called *Spigelian*) is placed at the hinder border of the liver, on the right-hand side of the fissure of the ductus venosus. It is bounded behind and on its own right side by a short and deep fissure (or rather fossa) called the *fissure* of the *vena cava*, because that large vein runs along it.

In front the Spigelian lobe is bounded by the *transverse* or *portal fissure*, which crosses the under surface of the left half of the right lobe of the liver, and runs, almost at right angles, into the longitudinal fissure. It is into this fissure that the portal vein, the hepatic artery, and the great nerves enter, and it is from it that the bile-duct proceeds to convey away the biliary secretion. The portal fissure runs to the right, beyond the limits of the Spigelian lobe. That part of the substance of the liver which is situate behind this outer part of the portal fissure is called the *caudate lobe* (Fig. 385, *c*), and is a sort of

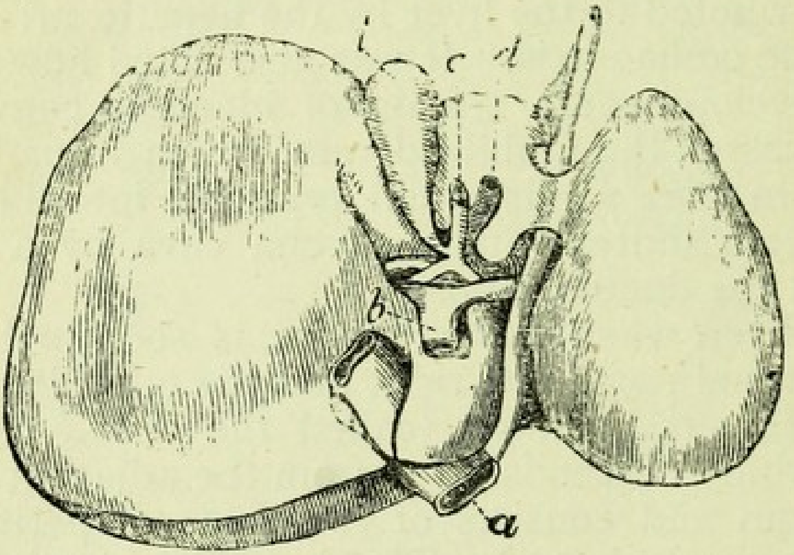

FIG. 383.—THE LIVER VIEWED FROM BELOW.
a, vena cava ; *b*, vena portæ ; *c*, the ductus communis choledochus ; *d*, hepatic artery ; *l*, gall-bladder.

ridge which proceeds from the base of the Spigelian lobe to the under surface of the great right lobe, and is in part limited behind by the vena cava. That part of the right lobe which is in front of the portal, or transverse, fissure is marked by a depression in which lies a pear-shaped bag, called the *gall-bladder*, which has its blind end (or fundus) forwards. The anterior end of this depression often notches the anterior margin of the great right lobe of the liver (Fig. 385, *cf*).

The bile, or *hepatic*, duct descends from the portal fissure, in front of the vena porta, and meets the duct of the gall-bladder—termed the *cystic duct*—at an acute angle. The common duct formed by the union of these two is called the *ductus communis choledochus*, and this passes into the duodenum side by side with the pancreatic duct, the two opening into the intestine by a common orifice.

15. In that man possesses a liver, he agrees, as has been mentioned in the First Lesson, with all the other members of his sub-kingdom; and in that he possesses a solid liver he agrees also with all, excepting only the Lancelet, in which

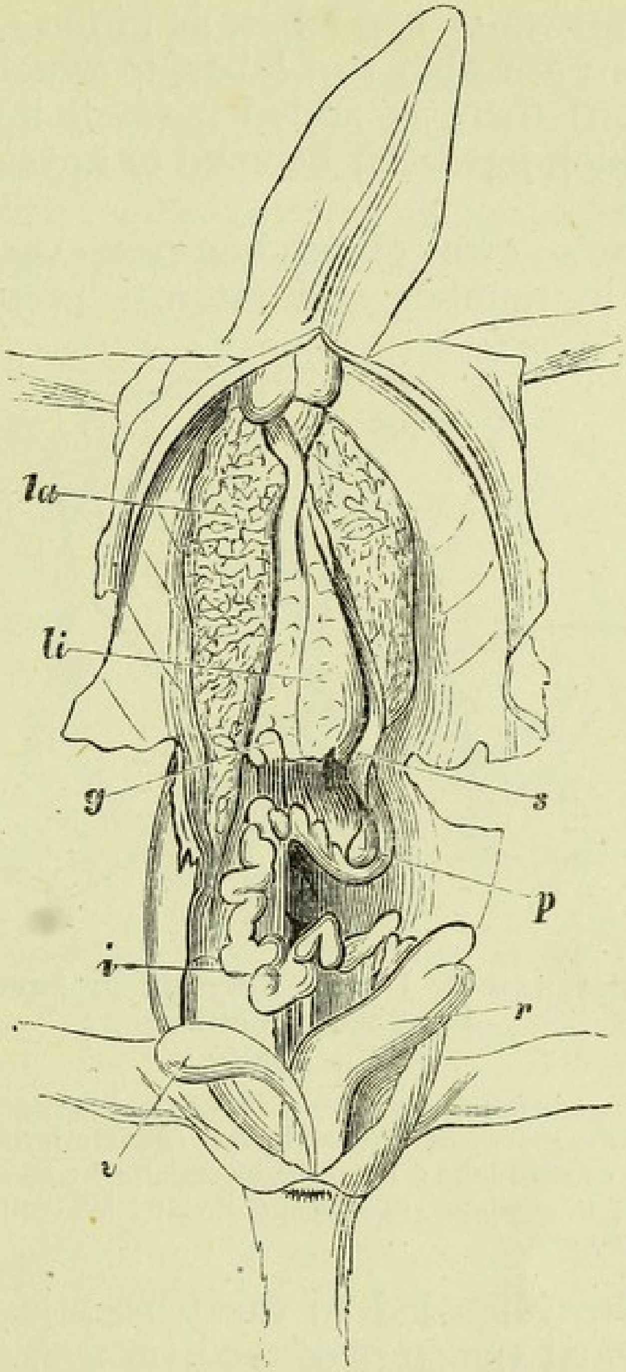

FIG. 384.—VISCERA OF LIZARD (*Calotes*).
(*After Salverda.*)
la, lung; *li*, liver; *g*, gall-bladder; *s*, stomach; *p*, pancreas; *i*, intestine; *r*, rectum; *e*, bladder.

animal this organ is a mere cæcum-like, saccular diverticulum (or offshoot) of the intestine, with its apex turned forwards.

The liver may attain a much greater complexity, as regards the number of its lobes, than we find in man, but in the majority of Vertebrates (in all, that is, below his own class) it is almost always very much more simple. Thus, in Fishes the liver consists generally of one undivided mass, or of two lobes, as in the Cod; or three, as in the Carp and Rays—very rarely of more, as in the Tunny.

In Reptiles the liver is single, as in the Chameleon and Serpents, or consists of two lobes, as in the Crocodile.

In Birds there are also two lobes, to which sometimes (as *e.g.* in the Swan) there is added a small intermediate lobe at the back, which has been deemed to answer to man's Spigelian lobe.

It is in man's own class, however, that the varieties greatest both in number and interest present themselves.

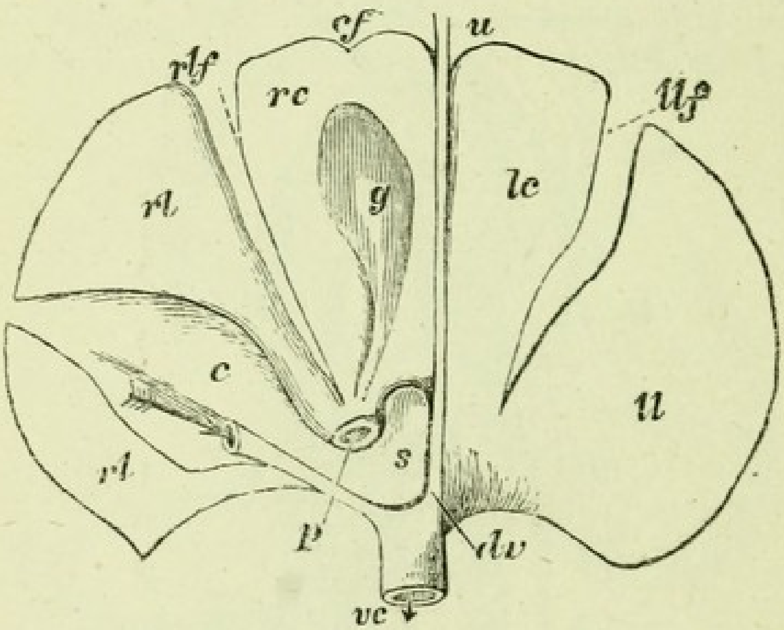

FIG. 385.—IDEAL DIAGRAM OF UNDER SURFACE OF LIVER, the front margin being turned upwards.

(*After Flower.*)

c, caudate lobe; *cf*, cystic notch; *dv*, remnant of ductus venosus; *g*, gall-bladder; *lc*, left central lobe; *ll*, left lateral lobe; *llf*, left lateral fissure; *p*, portal fissure; *rc*, right central lobe; *rl*, right lateral lobe; *rlf*, right lateral fissure; *s*, Spigelian lobe; *u*, remnant of umbilical vein; *vc*, vena cava. The arrow points to the vena cava.

The study of them has led to the perception that the most definite and typical structure of the liver is as follows:—(1), A Spigelian and (2) caudate lobe, each defined as in man; (3 and 4), two divisions of that part of the liver which lies on the left side of the broad ligament, and which are named respectively the "lateral left lobe" and the "central left lobe;" (5), the lobe which supports the gall-bladder, and which is called the cystic, or "central right lobe;" (6), the extreme right part of the great right lobe, often separated from the central right lobe by a fissure, and named the "lateral right lobe."

Further subdivision is rare, though it may exist, as *e.g.* in the Rodent *Capromys*, which has a liver consisting of many very small lobules; and in the Camel, which has numerous small superficial lobules on that organ. In the Seals also there are many secondary fissures.

The left lateral lobe may be very little developed, as in *Semnopithecus*. The same may be the case with regard to the left central, as in the Noctule Bat.

The right lateral lobe may be excessively small, as in the Hare. The caudate lobe may be absent, and the Spigelian quite rudimentary, as in the Wombat.

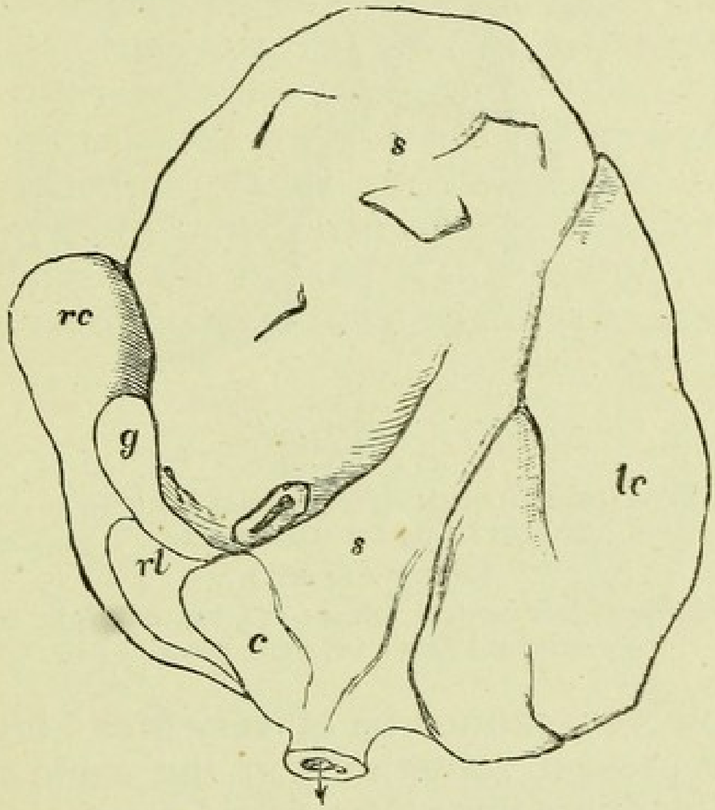

FIG. 386.—LIVER OF THE TWO-TOED SLOTH (*Cholœpus*) seen from beneath, its front margin being turned upwards.
(*After Flower.*)
c, caudate lobe; *g*, gall-bladder; *lc*, left central lobe; *rc*, right central lobe; *rl*, right lateral lobe; *s*, *s*, enormous Spigelian lobe.

The caudate lobe may attain a great size, as in the American Ape *Pithecia* (where it is as large as any other lobe of the liver), and in the Hedgehog. The Spigelian lobe may take on an excessive relative development, as in the little deer *Tragulus*, and above all in *Cholœpus*.

The liver may be even more simple than in man, as in the Dolphins, where it consists of two lobes only, and is very small. It may, as in the Hippopotamus, have no fissures whatever visible, the representative of the umbilical vein running deep and enclosed in the substance of the liver.

In possessing a gall-bladder man resembles the great majority of Vertebrates, yet it may be absent in the highest and the lowest classes. Thus in Fishes it is wanting in a few species, as *e.g.* in the Lamprey and *Pristis.* In Birds it is wanting in most Parrots and Cuckoos, as well as in the Pigeons. Amongst Mammals it is absent in the Cetacea, the Sloths, the Elephant, the Camel, the Hyrax, Horse, Tapir, and Rhinoceros. The presence or absence of

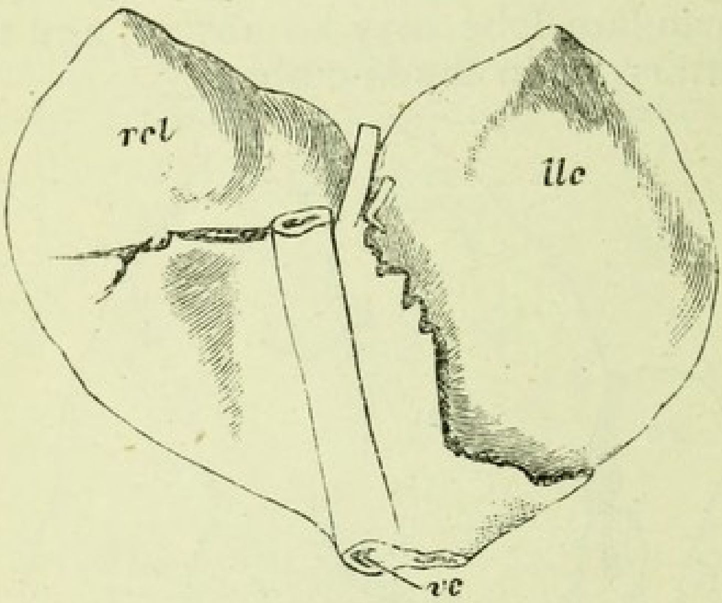

FIG. 387.—LIVER OF THE DOLPHIN (*Delphinus*) seen from beneath, its front margin being turned upwards.
(*After Flower.*)
llc, united left lateral and left ventral lobes; *rcl*, united right central and right lateral lobes; *vc*, vena cava.

this organ, however, cannot be of very great importance, as it is absent or present sometimes in the same species; and even two gall-bladders have been found coexisting in an individual Giraffe. The gall-bladder may be placed exceptionally on the left side, as in the Thylacine. It may be, as it were, inverted, perforating part of the liver and appearing on the upper surface, as in Lemuroids, e.g. *Galago.*

Where a gall-bladder is wanting, the bile-duct may—as in the Elephant—be dilated at its entrance into the duodenum.

The colour of the liver may differ strikingly from that which we find in man. This is especially the case in Fishes, where it may be bright red, as in *Holocentrum Orientale;* or yellow, as in *Atherina presbyter;* or green, as in the Lamprey.

The liver may also be much less dense in consistency than in man—as in Fishes generally; and in aquatic Mammals, such as the Cetacea, Seals, and Otter, it is said to be softer than in other kinds of the same class.

16. The PERITONEUM is, as was mentioned at the beginning of this lesson, a serous membrane lining the cavity of the abdomen, and reflected, from its posterior wall, over the viscera which the abdomen contains, and indeed more or less completely embracing them, but nevertheless really retaining them external to its proper cavity, as it is a completely closed sac.

To understand fully this complex structure it will be well to revert to what was said regarding embryonic development.

It will be remembered that the laminæ ventrales split, each lamina thus forming an outer and an inner lamella; that the two outer lamellæ meet ventrally and form the abdominal wall of the body; and that the two inner lamellæ also meet ventrally and form the alimentary canal—the space included between the two pairs of lamellæ (*i.e.* between the outer surface of the alimentary canal and the inner surface of the body-wall) constituting the pleuro-peritoneal cavity.

Now, the whole of the surface of this cavity becomes modified to form a continuous serous membrane, and this mem-

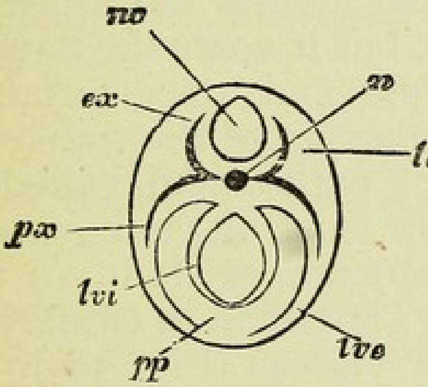

FIG. 388.—DIAGRAM OF THE DEVELOPMENT OF THE TRUNK AND ITS SKELETON, as shown in a section made at right angles to the trunk's long axis.

nc, neural canal; *ex*, epaxial cartilages ascending to surround it; *px*, paraxial cartilages descending in the plate, or layer (*lve*), external to *pp*, the pleuro-peritoneal cavity; *lvi*, internal plate of the split ventral lamina.

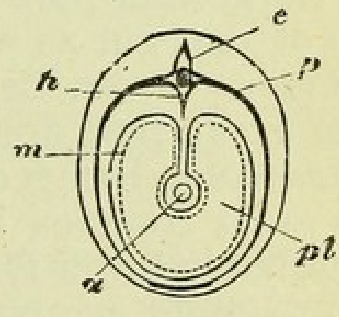

FIG. 389.—DIAGRAM OF THE FURTHER DEVELOPMENT OF THE TRUNK, as shown in a section similar to the last.

a, alimentary canal supported by a mesentery[2] formed of the dorsal portion of the inner parts of the split wall of the embryonic ventral laminæ; *e*, epaxial arch; *h*, hypaxial arch descending in the median line in the root of the inner part of the split wall of the ventral laminæ; *p*, rib, bifurcating proximally and abutting ventrally against the sternum, which thus completes the paraxial arch; *m*, peritoneum, bounding on all sides *pl*, the pleuro-peritoneal space.

brane is the peritoneum. But the root part of the inner pair of lamellæ—*i.e.* that part which intervenes between the alimentary canal and the axial skeleton—diminishes and ultimately disappears with the exception of the serous membrane coating it, and thus, the two serous coats of its two sides meeting together, the alimentary canal comes to be slung by means of them from the skeletal axis in a peritoneal fold, or, as it is called, *mesentery*. In man and in allied animals, however, the alimentary canal is very tortuous and convoluted, and has annexed to it many complex accessory structures. Thus the lining peritoneal membrane, passing from one digestive organ to another and wrapping them round in various degrees and with various adhesions, comes to form a wonderfully complex structure.

In man, beginning from the under surface of the diaphragm, we find a fold of peritoneum constituting the falciform ligament, before described, attaching the liver to the diaphragm. The peritoneum then descends, coating the abdominal aorta and inferior vena cava. It also descends, and coats the liver. From the under surface of the liver it again descends to the stomach, in a double fold of membrane called the *gastro-hepatic omentum*. It next encloses the stomach and also the spleen. It also invests the intestines except the greater part of the rectum, but it coats the anterior surface of that gut as well as the upper and inner surface of the bladder. From between the stomach and the transverse colon, a great, free, apron-like flap of peritoneum, called the *great omentum*, hangs down loosely in front of the bowels.

This great complex bag, the peritoneum, exists in all Vertebrates, but in lower forms is greatly simplified in conformity with the simple arrangement of the viscera (Fig. 390). In Fishes its cavity sometimes communicates with the exterior by two apertures placed near the external termination of the alimentary canal, as *e.g.* in the Lamprey, Eel, Salmon, and others. It may communicate by a single opening placed further forwards, as in the Lancelet. It may communicate with the pericardium, *e.g.* in Myxine, the Sturgeon, and Sharks, as was indicated in describing the diaphragm.

It may, as in most Reptiles, and in Batrachians and Birds, line uninterruptedly the thoracic and abdominal cavity, forming one pleuro-peritoneal sac; thus differing from man (and Mammals), in whom, as we shall see in the next Lesson, the thorax has its own proper serous sac, that muscular partition, the diaphragm, dividing the two cavities in Mammals. The peritoneum may be delicate and transparent, as in man. It is so in his class generally, and in Birds. It may, however, be black, as is sometimes the case in Reptiles and

Fishes. It may have a silvery metallic lustre, as often in the last-named class.

It may, as in Birds, form great cells which communicate with the lungs, and thence become inflated with air.

The peritoneum may be incomplete, being reduced, as it were by local atrophy, to shreds and patches, as in many cartilaginous Fishes, *e.g.* the Sturgeon.

Instead of an omentum passing post-axially as in Mammals, two such structures may extend pre-axially (*i.e.* towards the head) from the pelvic region, as in many Lizards.

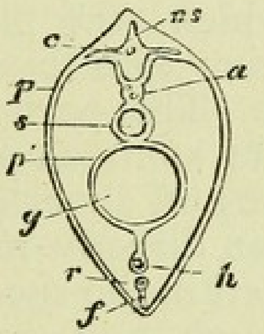

FIG. 390.—DIAGRAM OF A TRANSVERSE SECTION OF A LIZARD, showing the stomach, spleen, lesser omentum, and falciform hepatic ligaments, all in their typical or median position.

(*After Pittard.*)

ns, neural spine ; *c*, neural canal ; *p*, outer surface of body ; *p'*, peritoneum lining the body-cavity and investing the viscera ; *a*, the aorta ; *s*, the spleen ; *g*, the stomach ; *h*, the gall-duct ; *f*, the falciform ligament of the liver ; *r*, the pleuro-peritoneal cavity.

The whole intestine (*i.e.* both the great and small intestines) may be suspended by one continuous mesentery, even in man's own class, as in the Shrew and the Elephant.

17. In the DEVELOPMENT of the alimentary system the first notable modification is the splitting of the laminæ ventrales, as already mentioned. When by the ventral union of the inner laminæ the alimentary canal is formed, this canal is at first a straight tube closed at both ends, and extending along the ventral aspect of the axial skeleton.

After a time the tube, towards the middle of the body, bends away from this axis in a sharp ventral curve, while that part of it on the pre-axial side (side next the head) of the curve dilates and becomes the stomach. The part on the post-axial side of the curve becomes the transverse colon, while the intervening loop becomes greatly lengthened and excessively convoluted to form the small intestine and ascending colon, a little bud-like offshoot laying the foundation of the cæcum. As we have seen, this proximity of the transverse colon to the stomach and duodenum, thus early initiated, persists with great constancy. Each of the two ends of the alimentary canal becomes perforated by means of a depression which appears on its surface, and which deepens till it opens into the nascent alimentary canal.

The large intestine is at first of less capacity than the small, and the vermiform appendix is at first as wide as the cæcum.

Immediately below the dilatation for the stomach a very small offshoot grows out from the alimentary canal, and around this a soft mass of tissue is developed—the future liver. The transitions which take place with regard to the blood-vessels in connexion with this part have been already described in Lesson X. The part of the alimentary canal which is pre-axial to the stomach becomes, of course, the œsophagus. It also gives off diverticula, but as these (afterwards the lungs) are not directly related to the alimentary system, they will be noticed in the succeeding and last Lesson.

18. Thus a certain rough and general approximation to the earlier conditions of the digestive system found in man manifestly persists in lower Vertebrata; in some Fishes the alimentary canal being, as we have seen, of nearly uniform width throughout its course, without even a dilatation to form a distinct stomach. The liver in its earliest condition recalls its permanent form in Amphioxus. As we ascend through the Vertebrate series, we find in the highest class a greater complication of definite, distinct, and mutually related parts, although the ascent is by no means regular. Not in man do we find the most complex stomach, but in the Sheep. Not in him is the cæcum at its maximum, but in the Indris and some others before mentioned. Valvulæ conniventes, indeed, are a marked character of the small intestine of man, but they are yet more marked in the Ornithorhynchus. The liver may be much more complex than in him, but it may also be more simple even in his own class. The tongue may be much longer and more mobile; it may also be much shorter and less mobile, or may abort altogether. Salivary glands may be completely absent; they may, on the contrary, attain a size and complexity to which those of man are far from attaining. The alimentary system, then, hardly agrees with the nervous system in presenting marked and readily appreciable characters, by which man's organization exhibits an evident and unmistakable superiority, though a certain superiority probably exists in the reciprocal co-ordination of its parts.

LESSON XII.

THE EXCRETORY ORGANS.

1. IN the First Lesson of "Elementary Physiology," § 23, while explaining the nature of the excretory process and its most general conditions, it was stated that the EXCRETORY ORGANS are three in number, namely : (1), the skin ; (2), the ungs ; and (3), the kidneys. The description of the skin and ts various appendages has formed the subject of our Seventh Lesson. Nevertheless, the consideration of its glandular structure was purposely deferred to the Twelfth Lesson, and nay be here considered, with the lungs and kidneys together vith adjoined and adjacent structures not yet treated of.

The lungs, however, are importers of oxygen (for the ıëration of the blood) as well as excretory organs ; it is not, hen, surprising that the external skin may assume that function also, as in fact we found (when considering the circulating ystem) to be the case in Batrachians.

The function of importing oxygen into the blood is performed in many animals by a set of organs of which no representative exists in man, and which, therefore, are not referred o in the Lessons of "Elementary Physiology," though they nust occupy no inconsiderable portion of our concluding Lesson of "Elementary Anatomy." The organs in question mentioned in our First and Tenth Lessons) are the gills, or *ranchiæ*. These are delicate processes of skin, richly supplied vith blood and capable of absorbing oxygen, not by the ecomposition of the water in which they float, but by the bsorption of oxygen from the particles of air which are mixed p with and dissolved in that water. Such structures, as might e expected, are only found in animals which live in or requent water, whether fresh or salt, though not all animals hich frequent water have gills.

Thus, in being destitute of branchiæ, man agrees not only ith the whole of his class (including, of course, the Whales and Porpoises), but with the Sauropsida also; while in possessing lungs he agrees with all Vertebrates, except Fishes, which with the exception of the Mud-fish (*Lepidosiren*) are destitute of true lungs. First, then, may be considered the lungs as they exist in man and Vertebrates generally. After that will naturally follow the consideration of gills, or branchiæ, parts which in function answer to the lungs of man, though they have no resemblance in structure or mode of development.

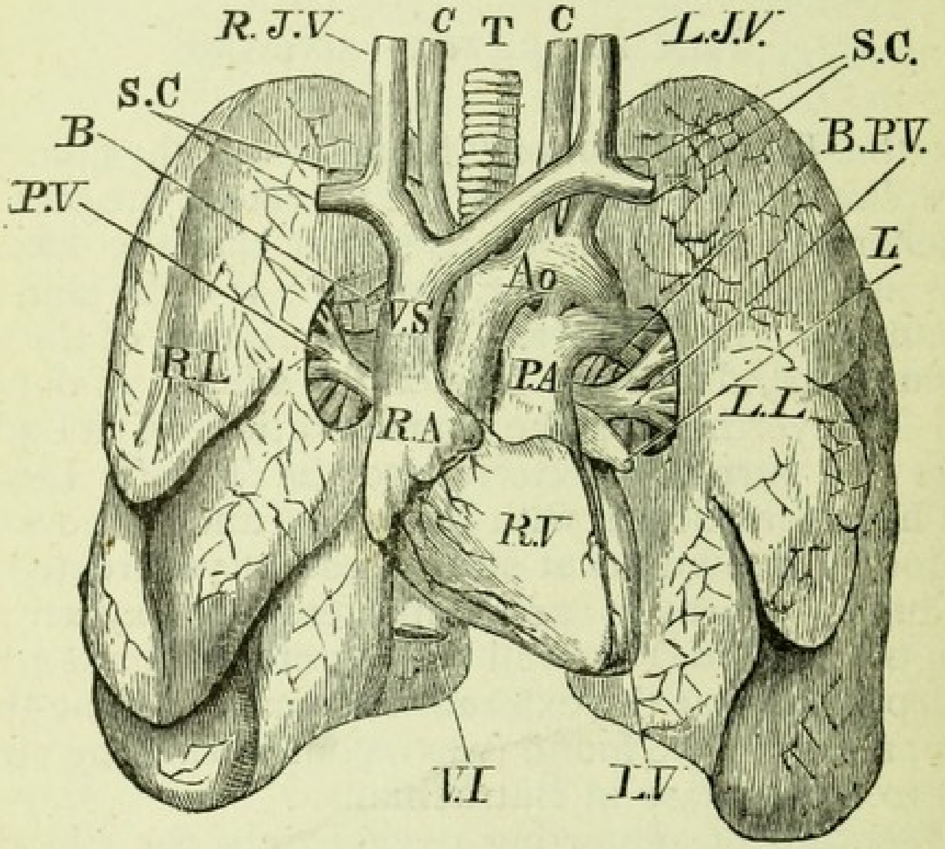

FIG. 391.—THE HEART, GREAT VESSELS, AND LUNGS. FRONT VIEW.

RV, right ventricle; *LV*, left ventricle; *RA*, right auricle; *LA*, left auricle; *Ao*, aorta; *PA*, pulmonary artery; *PV*, pulmonary veins; *RL*, right lung; *LL*, left lung; *VS*, vena cava superior; *SC*, subclavian vessels; *C*, carotids; *R* and *LJV*, right and left jugular veins; *VI*, vena cava inferior; *T*, trachea; *B*, bronchi. All the great vessels but those of the lungs are cut.

2. The LUNGS of man have been shortly described in the Fourth Lesson of "Elementary Physiology." They are two in number, one placed on each side of the heart, and (with it and the blood-vessels, air-passages, and œsophagus) fill up the entire cavity of the thorax. The lungs are attached, by their roots, to the two branches of the windpipe (hereafter to be described), and to the great vessels proceeding to and fro between the lungs and the heart.

From this attachment each lung hangs down freely suspended in a short serous sac—the *pleura*—which closely invests it. This is the proper serous sac of the thorax.

The two pleuræ line the right and left halves of the thorax, and are reflected over the two lungs at their roots respectively. In this way the two adjacent (inner) sides of the two pleuræ traverse the thorax from behind forwards. They are not, however, in contact, but separated by two interspaces termed *mediastina*.

The *anterior* mediastinum contains the heart in its pericardium, as described in our Tenth Lesson.

The *posterior* mediastinum contains the œsophagus, the aorta, the vena azygos, and the thoracic duct, together with the pneumogastric nerves.

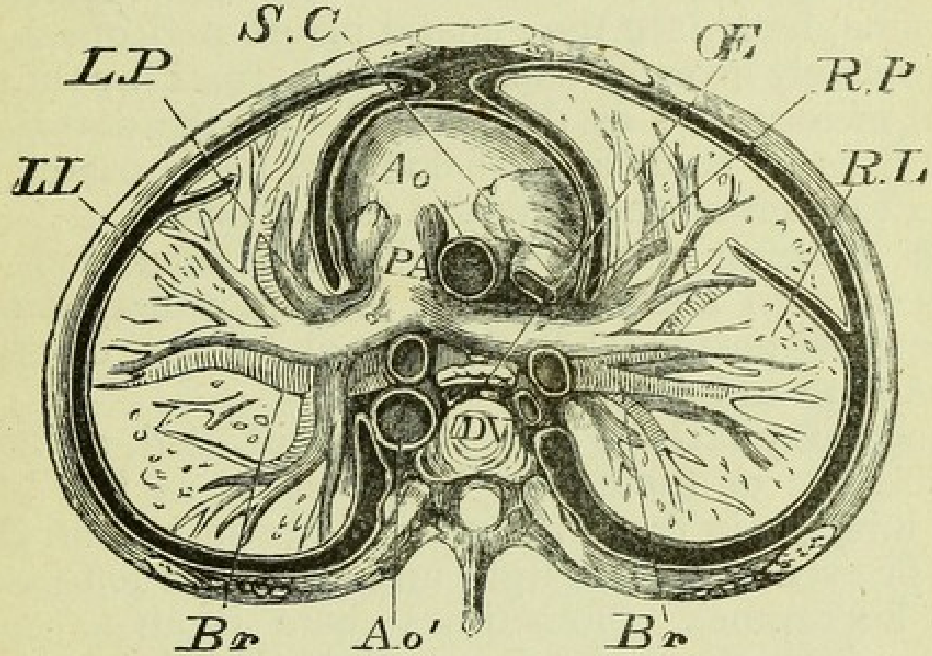

FIG. 392.—TRANSVERSE SECTION OF THE CHEST, WITH THE HEART AND LUNGS (EACH LUNG INVESTED WITH ITS PLEURA) IN PLACE.

DV, dorsal vertebra, or joint of the backbone; *Ao*, *Ao'*, aorta, the top of its arch being cut away in this section; *SC*, superior vena cava; *PA*, pulmonary artery, divided into a branch for each lung; *LP*, *RP*, left and right pulmonary veins; *Br*, bronchi; *RL*, *LL*, right and left lungs; *Œ*, œsophagus.

Each lung is conical in shape, and has a broad, concave base, which rests upon the diaphragm. The inner surface of each lung is turned towards the anterior mediastinum, and is adapted to the convex pericardium.

The right lung is shorter and wider than the left, and is divided by two notches into three portions or lobes. The left lung has only a single notch and two lobes.

Beneath the serous coat, each lung has a layer of cellular membrane, mixed with much elastic tissue, which passes in between the minute air-tubes and air-cells, as described in § 8 of the Fourth Lesson of "Elementary Physiology."

In *development* the lungs first make their appearance as two little bulgings (or sacs) from the ventral side of the œsophageal part of the alimentary canal. These little sacs afterwards elongate, and ultimately come to hang by a single and common supporting tube.

At first simple in structure, they gradually acquire the complicated condition which subsequently exists.

3. In the free suspension of the lungs in the thoracic cavity man agrees with all the other members of his class, but they may be fixed by cellular tissue to the dorsal side of that cavity, as in Birds and Chelonians.

Similarly their enclosure in two pleuræ is an exclusively Mammalian character. The lungs may, as in Batrachians and Saurians, hang into the general pleuro-peritoneal cavity, being completely invested (except at their roots) by the pleuro-peritoneal membrane; or they may lie on the dorsal side of that cavity, as in Birds and Chelonians, being coated by the pleuro-peritoneum on their ventral aspect only.

Instead of being confined to the neighbourhood of the heart, as in man and his class, the lungs may extend to nearly the most post-axial part of the abdominal cavity, as in the *Amphiuma* and *Siren.*

The lungs may each be single and undivided, as in Birds and Cetaceans; or there may be as many as five lobes in the right lung (as in the Hamster and Marmot), and three in the left—or even six in the right and five in the left (as in the common Porcupine). Sometimes there is an azygos lobe proceeding from the right lung, and placed between the heart and the diaphragm, as in *Ornithorhynchus.* This may exist when the lungs are otherwise undivided, as in the Elephant.

The right lung may be twice as large as the left, even in man's class, as in the Musk Deer and Porcupine.

The lungs may be nearly equal in size, as in Frogs; they may, on the other hand, be still more unsymmetrically developed than in the Musk Deer. This is the case in Serpents and *Ophiomorpha;* and one lung may be quite rudimentary, as in the common Ring Snake; or absent altogether, as in at least some kinds of Viper. The right lung may be much smaller than the left, as in the snake-like Batrachian *Gymnophiona.*

As regards the minute structure of the lungs, man agrees with the whole of his class. The substance of these organs, however, may consist, as in Birds, of fine tubes (the walls of which are minutely sacculated), given off at right angles from other tubes, which again spring at right angles from the bronchi or primary divisions of the windpipe.

The lungs may be cellular throughout their extent, while yet the bronchi do not give off branches within them, as in *Chelonia* and *Crocodilia*.

They may be cellular only near their root, the more post-axial part of the lung being a simple membranous air-bag, as in Serpents.

Part of the arterial blood, carried by the pulmonary artery, instead of going to the lung may be conveyed by small branches to the œsophagus, as in *Menopoma*, *Amphiuma*, and *Siren*.

Part of the venous blood of the lungs, instead of returning direct to the heart, may enter the veins of the trunk, as in *Proteus*.

FIG. 393.—DIAGRAM OF A LOBULE OF THE LUNG OF A BIRD, GREATLY MAGNIFIED. (*After Thomas Williams.*)

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*, or air-bladder, and a structure of the kind is found in most Teleostean and in all Ganoid Fishes.

A swim-bladder, however, may closely approximate to a lung, as in *Ceratodus*, where, though blood is not brought to that bladder directly, as in *Lepidosiren*, yet blood is sent directly to the heart by a pulmonary vein which opens into the atrium of the heart, or chamber representing the (as yet undifferentiated) auricles.

The swim-bladder may present a great variety of conditions.

Thus, it may be double and connected with the ventral part of the œsophageal portion of the alimentary canal by a short tube, the *ductus pneumaticus*, as in *Polypterus*; or single and connected more with the side of the same part, as in *Ceratodus* and *Erythrinus*. It may be connected with the dorsal part of the œsophagus, as in *Lepidosteus* and the Carp; or with the cardiac part of the stomach, as in the Herring.

The ductus pneumaticus may be long, narrow, and bent, as in the Carp; or short, straight, and wide, as in *Lepidosteus*.

It may abort altogether in the adult (the swim-bladder thus becoming quite separate from the alimentary tube), as in the Cod, Perch, and very many others.

In shape the swimming-bladder may bifurcate anteriorly as in *Lucio-perca*, or posteriorly as in *Acanthurus;* or it may be constricted towards its middle, as in the Carp; or it may send out two blind processes on each side, as in *Corvina;* or a multitude on each side, as in *Johnius.* Finally, the swim-bladder may give out processes from each side, each process bifurcating dorsally and ventrally, and each dorsal and ventral bifurcation again dividing and anastomosing with processes of the opposite side, the whole complex structure being invested by folds of the peritoneum. This maximum of complexity is exhibited by *Callichthys.*

FIG. 394.—AIR-BLADDER OF THE TELEOSTEAN FISH, *Johnius lobatus.*

It may be connected with the internal ear, as in the Carp (*Cyprinus*) and Loach (*Cobitis*), by the intervention of small special ossicles analogous to, but not homologous with, the auditory ossicles of man. In the Loach the bladder seems chiefly related to some auditory function, as it only extends to the third vertebra.

The cavity of the swim-bladder may be simple, as is usually the case; it may be divided by septa, as in *Bagrus;* it may, finally, be so subdivided into cells as to be like the lung of a Reptile, as is the case in *Amia.*

Retia mirabilia may exist in the swim-bladder, as in the Cod.

Every representative of a lung may be absent, as in the Sharks, Rays, *Pleuronectidæ*, *Marsipobranchii*, and *Amphioxus*, in all of which there is no swim-bladder.

The mechanism of aërial, pulmonic respiration, which exists in man, exists also in all Mammals—the diaphragm being their main agent in filling and emptying the lungs.

The lungs, however, may be filled and emptied by alternate movements of the sternum towards and away from the vertebral column. This is the case in Birds (Fig. 76), where such movements are aided by the synovial articulations between the sternal and vertebral ribs.

Analogous motions of the abdominal muscles and ribs alternately dilate and contract the body-cavity, and so fill and empty the lungs—in Saurians and Serpents.

In Chelonians, where the ribs are immovably fixed, and the ventral side of the body is covered with a solid exo-skeleton (the plastron), inhalation is effected by forcing air down the windpipe by an action analogous to swallowing. The mouth being filled with air, the posterior nares and all possible exits are closed, except that leading to the lungs; and down that exit air is forced by a contraction of the muscles of the throat. Exhalation is effected by means of muscular contractions at the most post-axial part of the abdominal cavity.

In Batrachians (which are devoid of ribs, or have but very short ones) the respiratory movements are similarly effected, air being swallowed by contractions of the muscles of the throat, and expelled by those of the abdominal muscles. Thus to suffocate a Frog it is sufficient to keep its mouth *open*.

4. The lungs of man communicate with the mouth and so with the external air, by means of a single channel, the windpipe or TRACHEA; which divides at its lower end into two branches, termed BRONCHI, one bronchus going to each lung.

The *trachea* is a straight, permanently open tube, commencing above at the larynx (shortly to be described), which is, as it were, its expanded upper end. It descends, in the middle line, in front of the œsophagus, to opposite the third dorsal vertebra, where it is crossed in front by the arch of the aorta, and bifurcates, dividing into the right and left bronchus.

The trachea is formed of membrane strengthened by a series of from sixteen to twenty horizontal cartilaginous rings, which are not however complete behind, so that the hinder wall of the tube, being entirely membranous, is flattened. The tube is lined with mucous membrane, and its wall contains muscular fibres and cellular tissue, with glands, vessels, and nerves.

The *bronchi* have the same structure as the trachea, except that the cartilaginous rings are shorter and narrower. There are from six to eight in the right bronchus; from nine to twelve in the left.

Within the lung the bronchi divide and subdivide, like the branches, branchlets, and twigs of a tree. These successively smaller and smaller tubes are kept distended by successively smaller and more delicate cartilages, which are no longer in the form of rings incomplete behind, but are irregularly-shaped pieces of various sizes. The ultimate twigs are entirely membranous. The mucous lining of the tubes lines the ultimate air-cells themselves.

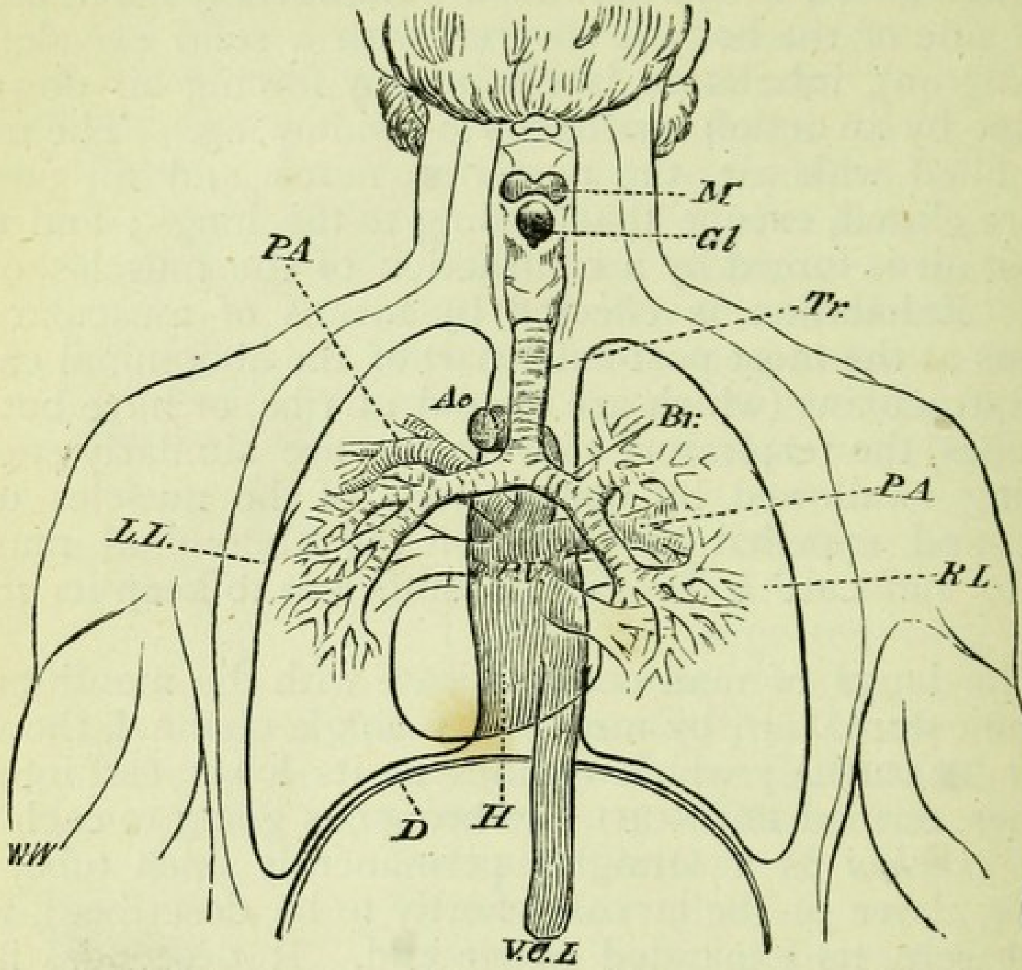

FIG. 395.—BACK VIEW OF THE NECK AND THORAX OF A HUMAN SUBJECT from which the vertebral column and whole posterior wall of the Chest are supposed to be removed.

M, mouth; *Gl*, glottis; *Tr*, trachea; *LL*, left lung; *RL*, right lung; *Br*, bronchus; *PA*, pulmonary artery; *PV*, pulmonary veins; *Ao*, aorta; *D*, diaphragm; *H*, heart; *VCI*, vena cava inferior.

5. In that he has a trachea, man agrees with all Mammals and Sauropsidans, and with the Ophiomorpha, *Menopoma*, and *Siren*, amongst Batrachians. A trachea may, however, be entirely wanting, the lungs springing immediately from the larynx, as in the common Frog and Toad. It may be present, but short and wholly membranous, as ir *Salamandra.*

It may be much shorter relatively than in man in his owr class (as *e.g.* in Whales), or it may be much longer, as ir Ruminants. In Birds, however, it attains its maximum o relative length.

In so far as the trachea of man is a straight tube, it agree with that of all other members of his class, except the Three toed Sloth (*Bradypus*), in which it is bent abruptly on itself in a single fold; and with Reptiles, except some Crocodiles and Chelonians in which it is similarly bent. It may be still more bent, even coiled (as in many Birds), and the coils may lie beneath the skin, external to the pectoral muscles, as in *Anas semi-palmata*, or sheltered in an excavation in the keel of the sternum, as in the common Crane and male wild Swan.

In that there are two bronchi and no more, man agrees with the great majority of Vertebrates that possess a trachea. One bronchus, however, may abort with its appended lung (as in many Serpents), or there may be a third bronchus, as in Ruminants, the Hog, and Cetaceans.

The rings of the trachea may be ossified, as in most Birds. They may be as few as three, as in the Dugong; or as many as 110, as in the Camel; or even 300, as in the Flamingo and the Boa. They may completely encircle the tube, as in Birds generally, and in the Horse (though in most Mammals they are incomplete behind, especially in Rodents). Some of the rings of the trachea may be incomplete in front, as in the Emeu.

The trachea may increase in size downwards, as in the Turkey; or it may present a more sudden enlargement before bifurcating to form the bronchi, as in the Merganser; or two such enlargements, as in the Goosander. It may be divided by a septum extending from above downwards, as in the Penguin and *Sphargis*.

A special structure may be developed (as in most Birds) at the junction of the trachea and bronchi. This is the *syrinx*, and is the organ of song in singing birds. It is also called the lower larynx, and is quite a different part from the true or upper larynx, shortly to be described.

The syrinx is generally formed by the coalescence or modified shape of the lower rings of the trachea and the upper ones of the bronchi, the latter being incomplete internally, so that the sides of the bronchi which look towards each other are at their upper part merely membranous, forming the *membrana tympaniformis*. Internally the syrinx is generally divided by a bar of bone, from the upper margin of which a delicate membrane ascends into the trachea, ending in a free concave margin, whence it is termed the *membrana semilunaris*. This highly vibratile membrane, together with two elastic folds of mucous membrane, placed one on each outer side of the commencement of each bronchus, are the special agents of song. Their action is modified by special muscles. Generally there are two pairs of muscles passing from the clavicles or sternum to the trachea; and in addition to these may be five or six pairs of muscles passing down from the trachea to the bronchial rings. These additional muscles are present in singing birds, but also in many birds that do not sing, as *e.g.* the Raven.

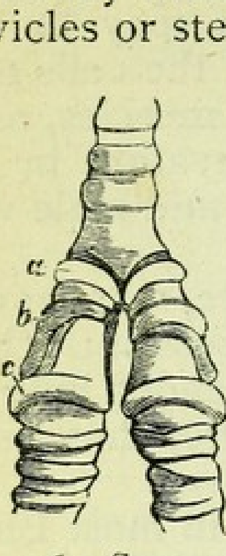

FIG. 396.—SYRINX OF A RAVEN.

a, b, and *c,* three bony structures.

There may be no membrana semilunaris, and only three pairs of additional muscles, in birds highly gifted as to their powers of emitting special sounds. Such is the case in the Parrots, where, however, the lateral elastic folds of membrane are well developed.

A syrinx may be formed by the trachea only (without the intervention of the bronchi), as in *Thamnophilus* and *Opetiorhynchus*, where the post-axial part of the trachea has delicate walls, and is flattened dorso-ventrally with six or seven delicate segments of rings, the rings being interrupted laterally. The additional muscles here pass from the part of the trachea above (pre-axial to) the syrinx to the tracheal ring beyond it.

A syrinx may be formed in each bronchus (without the intervention of the trachea), as in *Steatornis*, where more than ten rings in each bronchus may be counted before reaching the syrinx, and where a pair of muscles passes to each bronchus from the trachea.

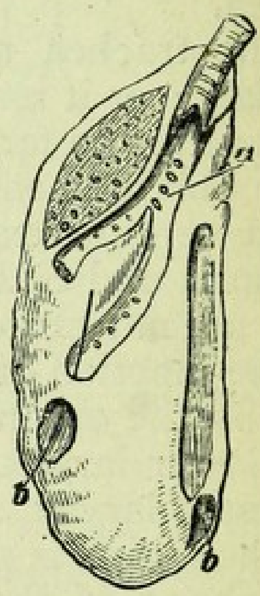

FIG. 397.—RIGHT LUNG OF A GOOSE.

(*After Owen.*)

a, bronchus; *b, b,* openings into air-sacs. In the two bronchi which are cut open are seen the apertures of their primary branches.

Bronchi may be absent together with the trachea, as in the common Frog and Toad. They may be absent though a trachea is present, as in *Siren.* They may open at once into the lung, without ramifying, as in Ophidians. They may traverse the lung, soon losing their cartilaginous rings, and having apertures in each side leading into the large pouch-like air-cells of the lungs, as in the Crocodile. They may similarly enter the lungs and lose their rings, but give off secondary branches at right angles, these again tertiary ones in a similar way, as in Birds (Fig. 393). Not only, however, may the bronchi be thus arranged (instead of dividing like the branches and twigs of a tree, as in man and Mammals), but they may open at the surface of the lungs into large air-sacs, as in Birds.

In Reptiles (amongst the Chameleons and Geckos) the lung may be drawn out, towards its post-axial end, into narrow prolongations which penetrate between the viscera. In Birds, however, there may be nine well-defined air-sacs, or greatly enlarged prolongations of the membrane of the bronchi. Two of these take origin respectively from the end of each main bronchus, and are the posterior, or *abdominal*, air-sacs. Four others are the pair of *anterior* and the pair of posterior *thoracic* air-sacs. They lie in the thorax on the ventral surface of the lung, and spring from primary branches of the bronchi. The seventh and eighth air-sacs are the *cervical* ones, and lie outside the thorax; the ninth air-sac—the *interclavicular*—is formed by the coalescence of what was at first a pair of sacs.

Very generally some of these air-sacs are prolonged into or communicate with the air-cavities of the bones. This is especially the case with the interclavicular, the cervical, and the abdominal air-sacs, but never with the thoracic ones.

6. The LARYNX of man has been already noticed in the Seventh Lesson of "Elementary Physiology," §§ 21–25.

The Larynx is the expanded upper part of the trachea sustained by cartilages, more or less movable, of modified forms and special names, opening at the back of the floor of the mouth in front of the entrance to the œsophagus, and behind the tongue.

The largest piece entering into the composition of the larynx is the *thyroid cartilage*,[1] which produces that prominence in the middle of the front of the throat, popularly known as Adam's apple. It is formed of two plates, united along the middle line in front, at an acute angle, but widely open behind. The hinder margins of these two plates are vertical and prolonged into a process both above and below. Each of the two upper processes is connected by a ligament with the tip of the corresponding great cornu of the hyoid bone, the body of which bone lies over the front of the thyroid cartilage. The hyoid is connected with the thyroid by the thyro-hyoid membrane, and is situate at the root of the tongue, giving origin to the muscles forming that gustatory organ.

[1] From θυρεός, a shield, and εἶδος.

Each of the two lower processes of the posterior margins of the thyroid articulates with the side of the cartilage next to be described.

This latter, the *cricoid*[1] cartilage, forms a complete ring, deepest behind (where the thyroid is open), placed beneath the thyroid cartilage, and forming the uppermost ring of the trachea, with both of which parts it is connected by membrane.

The *arytenoid*[2] cartilages are two in number, placed side by side, at a little distance from each other, on the posterior

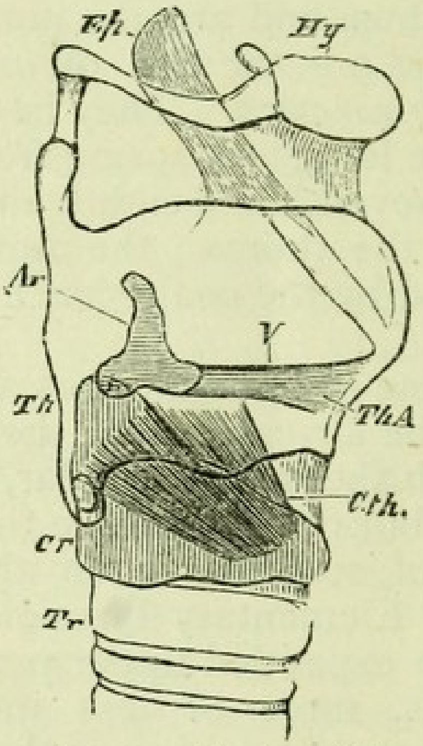

FIG. 398.—DIAGRAM OF THE LARYNX, the thyroid cartilage being supposed to be transparent, and allowing the right arytenoid cartilage (*Ar*), vocal ligament (*V*), and thyro-arytenoid muscle (*Th A*), the upper part of the cricoid cartilage (*Cr*), and the attachment of the epiglottis (*Ep*) to be seen. *C th*, the right crico-thyroid muscle; *Tr*, the trachea; *Hy*, the hyoid bone.

and highest part of the cricoid cartilage. Each arytenoid cartilage is pyramidal in form, and at the apex of each is placed an additional and minute cartilage, called that of *Santorini*.

The *epiglottis*[3] is a median, azygos cartilage, shaped somewhat like a leaf, placed in front of the upper opening of the larynx within the thyroid cartilage and the cornua of the hyoid. It ends in a narrow termination below, where it is attached by ligament to the depression at the front part of the inner surface of the thyroid cartilage.

[1] From κρίκος, a ring, and εἶδος.
[2] From ἀρύταινα, a sort of pitcher, and εἶδος.
[3] From ἐπί, upon, and γλωττίς, the aperture of the windpipe.

Finally, there are two more minute cartilages, called those of *Wrisberg*, each placed in the fold of mucous membrane proceeding, on each side, from the epiglottis to the top of the arytenoid cartilage.

The *true* vocal cords are two bands of elastic tissue, one of which proceeds on each side from the middle of the thyroid to the base of the arytenoid cartilage.

The *false* vocal cords are two folds of mucous membrane which similarly connect the thyroid and arytenoid cartilages.

Both kinds of vocal cords have their free edges turned inwards, and between them is the glottis (or upper opening of the windpipe), the exact form and size of which is regulated by delicate muscles which move the parts of the larynx one on the other—especially the arytenoid cartilages on the cricoid—as explained in the " Elementary Physiology."

Between the true and false vocal cords there is (on each side) a depression termed a *ventricle* of the larynx, and a small prolongation of this upwards on the inside of the thyroid is called a *laryngeal pouch*.

7. In so far as man has a larynx at all he agrees with all Vertebrates above Fishes, and in its general composition man's larynx agrees with that of other members of his class. Amongst Mammals, however, the laryngeal cartilages may be more or less ossified, as commonly in the Slow Lemurs. The larynx may be very much larger relatively than in man, as in the Howling Monkeys (*Mycetes*), where the thyroid cartilage may be three times the size of its human representative, while the os hyoides is almost gigantic, and excavated in such a way as to form a kind of thin bony bladder ; its excavation being an enormous exaggeration of the slight concavity on the hinder surface of the human hyoid. The lateral plates and lamellæ of the thyroid may meet together in the middle line behind (*i.e.* dorsally), as in the Ornithorhynchus. In contrast with this, the cricoid may be incomplete in front (*i.e.* ventrally), as in the Porpoise.

The arytenoid cartilages may be exceedingly prolonged upwards and united in the middle line, as in the last-mentioned animal, where they become enclosed together with the epiglottis in a sheath of mucous membrane, the whole forming a conical projection which is received into the posterior nares and embraced by the muscular soft palate. In this way the Porpoise can breathe securely while the mouth is full of water, or while food is passing to the œsophagus on either side of the dorsally prolonged larynx.

The cartilages of Santorini may be confluent in the middle line, as in the Hedgehog and *Pteropus*.

The cuneiform cartilages (of Wrisberg) may be more developed than in man, as in the Bear and Dog.

An extra, *interarticular*, cartilage may be developed between the bases of the arytenoids and the cricoid, as in the Hedgehog.

Vocal cords may be wanting, as in the Porpoise, or the upper cords alone may be obsolete, as in the Sloths and Armadillos. A median air-sac may be developed between the cricoid cartilage and the first ring of the trachea, as in *Ateles*.

The ventricles of the larynx may be greatly dilated and prolonged upwards so as to come into contact above, and at the same time there may be a pair of extra sacculi opening between the arytenoid cartilages and the glottis, while with these may coexist a median sac, filling an enormously expanded os hyoides. Such is the case in the Howling Monkeys (*Mycetes*).

A median air-sac may be developed from the thyro-hyoid membrane beneath the epiglottis, extending over the neck and to the armpits, as in some *Semnopitheci* and *Cynocephali*.

There may be, as in the Siamang Gibbon, a globular air-sac communicating with the larynx by two apertures in the thyro-hyoid membrane.

The ventricles of the larynx may be distended into enormous air-sacs, stretching over the chest, reaching to the armpits, and sometimes opening one into the other in the middle line of the body, as in the adult Gorilla, Chimpanzee, and Orang.

When we descend below man's class we see that the larynx may be much more, or but little more, imperfect in structure than it is in any Mammal.

Thus, in Birds we find thyroid, cricoid, and arytenoid structures, bony or cartilaginous. There may also be in some cases, as *e.g.* in the Swan, an epiglottis, but this is very rare. More often an epiglottis-like process of the thyroid may be developed. The cricoid may be represented by three pieces. Vocal cords are always wanting. The thyroid has often transversely extended fissures, or defects of solidification or ossification, probably related to the formation of this structure by the coalescence of primitively distinct rings or arcs.

Passing below Birds we find that both the thyroid and cricoid cartilages may be represented by a single circular cartilage with arytenoid cartilages annexed, as in the Crocodile. This circular cartilage may present defects of solidification like those just spoken of in the thyroid of Birds, as is the case in many Lizards. An essentially similar structure may be greatly prolonged, as in many Serpents (e.g. *Crotalus* and *Hydrophis*), where we find two elongated lateral bands connected by numerous transverse bars which are separated from each other by membranous interspaces. Arytenoid cartilages may be distinct or may be mere processes.

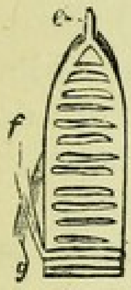

FIG. 399.—LARYNX AND UPPER PART OF TRACHEA OF A RATTLESNAKE (*Crotalus horridus*). Front (*i.e.* ventral) aspect.

(*After Heule.*)

e, epiglottis; *f* and *g*, muscles of larynx.

The simplest form of larynx seems to be that of *Proteus*, where there are only two slender elongated cartilages (the anterior ends of which appear to represent the arytenoids) placed one on each side of the slit-like glottis, which opens in the middle of the ventral wall of the pharynx.

A median air-sac may protrude anteriorly from the front of the larynx between the first ring of the trachea and the conjoined thyro-cricoid cartilage. Such is the case in the Chameleon.

8. As has been said, respiration may be effected by means of the air contained in water—*i.e.* by AQUATIC RESPIRATION. For this purpose the animals which so respire do not ordinarily take water into aquatic lungs as the air-breathing Vertebrates take air; but blood is copiously brought to a surface specially exposed to a flow of water almost constantly maintained by one process or another.

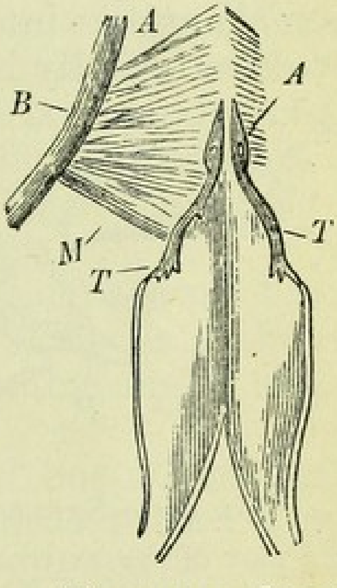

FIG. 400.—TRACHEAL STRUCTURE OF *Proteus*, opened from behind.

A, arytenoid part of each of the two cartilages; *T*, its tracheal part; *B*, branchial arch; *M*, muscle going from the branchial arch to the larynx.

It may be that this flow is effected by the action of vibratile cilia[1] propelling the water through numerous perforations in a greatly enlarged pharynx,

[1] For a description of cilia see "Elementary Physiology," Lesson VII. § 3.

as is the case in the Lancelet. This, however, is a solita exception. In all other cases the water is mechanical propelled by muscular contractions, and so made to pass ov delicate filaments or sheets (lamellæ) of membrane attache to a greater or less number of the visceral arches.

We may have (as in *Myxine* and in *Bdellostoma*) the gil in the form of a folded lining to six or seven pouches place in a linear series on each side of the body, each pouch con municating with the interior of the œsophagus by an apertur and thence receiving water. Each sac may open on th surface of the body by a separate aperture (as in *Bdellostom* and in the Lamprey), or each sac may open into a tub running along each side of the body external to the sacs, an terminating by an aperture placed far back on the ventra surface of the body (as in *Myxine*). In the latter case th water coming from the sacs passes out at one aperture on eac side of the body.

The sacs may open internally, not into the œsophagus bu into a median canal placed ventrally to the œsophagus (as i the Lamprey). This canal ends blindly at its post-axial en but pre-axially opens into the mouth by a valvular aperture.

These gill-sacs are not supported by solid viscer (branchial) arches internally, but may be, as in the Lampre protected externally by a cartilaginous framework or baske

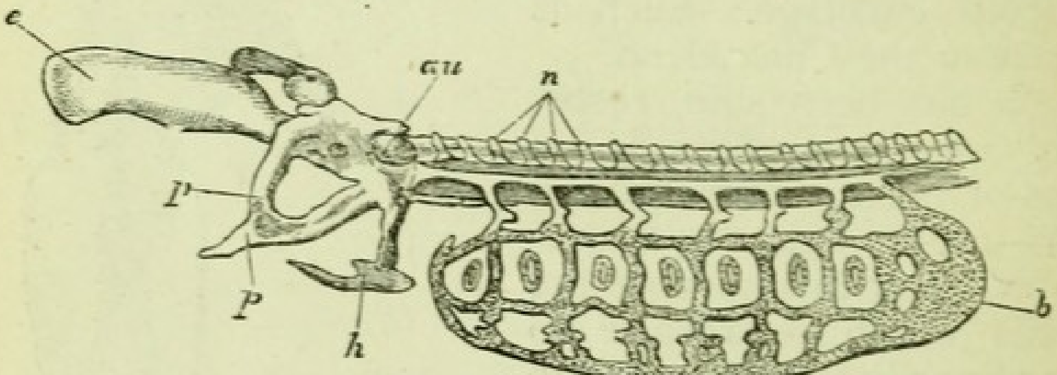

FIG. 401.—SKELETON OF HEAD AND GILLS OF LAMPREY.

hinder part of the external (paraxial) cartilaginous skeleton of the gills ; *au* auditory capsule ; *h*, hyoid ; *n*, neural arches ; *p*, palato-quadrate arch.

which, as we saw in Lesson VI., is a paraxial, skeleta structure.

The several gill-sacs are separated from each other by partitions which are not solid, cartilaginous structures.

The gills may be supported internally by solid (osseous or cartilaginous) "branchial arches," which, as we have seen in treating of the skeleton, are those visceral arches which suc- ceed the hyoidean and mandibular arches post-axially.

The branchial arches of osseous Fishes are made up of parts to which special names have been applied. They are attached to a median ventral series of pieces termed *basi-branchials*. The lower piece of each lateral arch is called

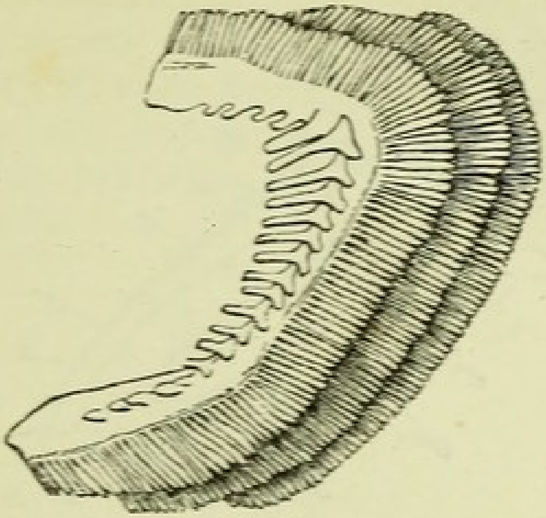

FIG. 402.—FIRST THREE BRANCHIAL ARCHES FROM THE LEFT SIDE OF A PERCH. On the outer (convex) side of each branchial arch the series of closely-set gill filaments (or leaflets or lamellæ) are seen to be attached. On the inner (concave) side of the first branchial arch are the series of elongated processes (supporting minute denticles) which help to prevent particles of food, or other foreign bodies, passing from the mouth to the gill chamber.

a *hypo-branchial*; to this succeeds a *cerato-branchial*, then an *epi-branchial*, and finally, at the summit, a *pharyngo-branchial*. These solid, supporting parts are not constantly or equally developed in all the branchial arches, as is shown by the annexed woodcut of these arches as they exist in the Perch (Fig. 403).

The partitions between the gills may extend from this solid internal support, outwards to the skin—as in the Sharks and Rays. In such case each gill-chamber opens separately on the side of the body.

The partitions may, however, extend but a very little way from such solid internal support, outwards to the skin, while the vascular gill-membrane remains elongated, and consequently hangs freely from the outer side of each branchial arch. This latter condition is that which obtains in ordinary osseous Fishes, *e.g.* Perch, Carp, Cod, &c Here we find but one large common chamber in which the filamentary gills float, but this chamber is protected by the extension backwards of a fold of skin (the *operculum*) supported internally by the opercular bones; and thus there comes to be in ordinary Fishes but a single large gill-opening on each side behind the head.

The gill-chamber is further protected by a membranous fold which lies within the opercular flap. This fold is the branchiostegal membrane, and is supported by the *bran-*

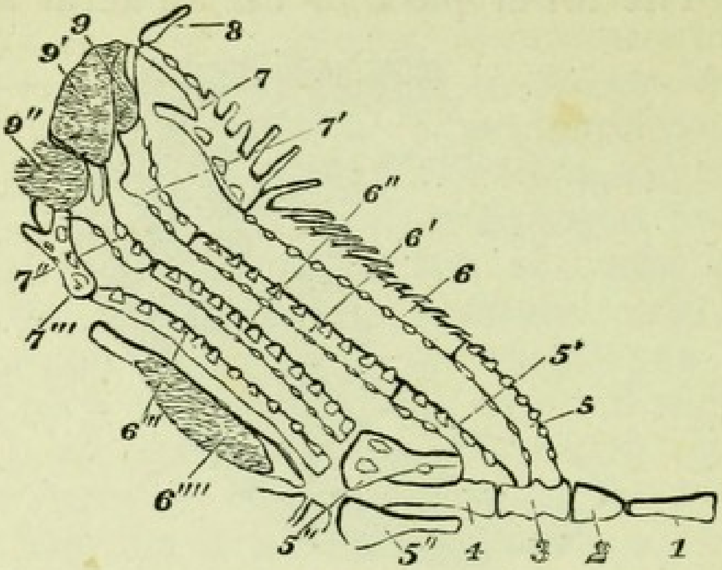

FIG. 403.—LEFT BRANCHIAL ARCHES OF PERCH. (*After Cuvier.*)

1, glosso-hyal; 2, 3, and 4, basi-branchials; 5, hypo-branchials; 6, cerato-branchials; 7, epi-branchials; 8, styliform pharyngo-branchial; 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 (inferior pharyngeal bone).

chiostegal rays, which (like the membrane itself) are attached to the post-axial side of the hyoidean arch.

The respiratory surfaces of the gills are supplied with water by the mouth, which continually takes in fresh supplies,

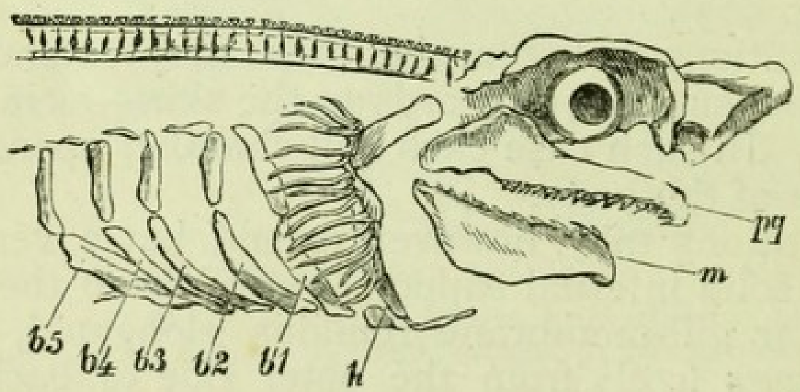

FIG. 404.—SKULL AND BRANCHIAL ARCHES OF A SHARK.

b^1—b^5, branchial arches; *h*, hyoidean arch; *m*, mandible: *pq*, palato-quadrate arch.

(*From the College of Surgeons' Museum*)

such supplies passing out, in the osseous Fishes, from the common opening behind the operculum; and, in the Elasmobranchs, from each separate aperture of the successive gill-chambers.

In the Tenth Lesson has been already described the mode in which the blood is brought to the gills from the heart, and from the gills to the general circulation, as also the changes which, in Batrachians, accompany the disappearance of the gills during the developmental metamorphosis.

The blood is carried in osseous Fishes (*e.g.* the Perch) along the convexity of each branchial arch both to and from the gill-filaments, the margins of which are skirted by arterial and venous branches, capillary vessels being interposed between them.

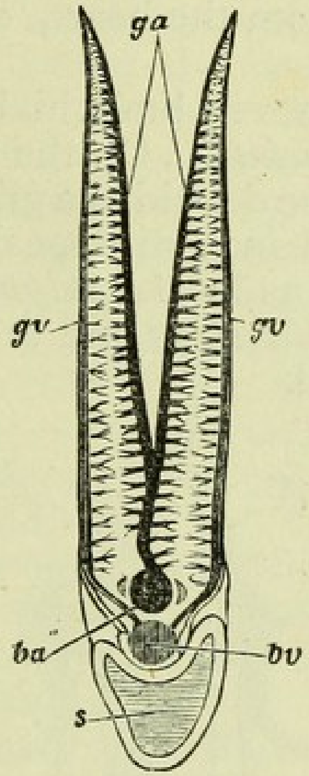

FIG. 405.—TWO LAMELLÆ (OR LEAFLETS) FROM THE GILLS OF AN OSSEOUS FISH, showing the course of the respiratory circulation.

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 down the groove of the branchial arch and has the branchial artery superficial and exterior to it.

Gills which are at first conspicuous but mostly disappear ultimately, are termed *external branchiæ*. Such are absent in almost all adult Fishes, though often present in the young condition, *e.g.* in young Sharks. In Batrachians, such as the Tadpole, they also disappear and give place to internal gills; but in some forms, e.g. *Axolotl* and *Menobranchus*, they persist throughout the whole of life as long plume-like appendages placed on each side of the neck.

Special respiratory structures may be added, as *e.g.* in the climbing Perch (*Anabas*), where the summits of the branchial arches — or epipharyngeal bones — become enlarged and curiously contorted to support an extension of vascular mucous membrane. Again, in *Saccobranchus* and *Amphipnous*, we find, by a very remarkable exception, a long lung-like sac (with a highly vascular internal surface) placed on each side of the body, and communicating with the mouth by an aperture placed between the first branchial arch and the hyoid. These organs receive blood from the aortic vessels coming from the heart, and transmit it to the dorsal aorta.

There may be six or seven branchial sacs, as in the Sharks *Hexanchus* and *Heptanchus*. On the contrary, not only may the fifth branchial arch be devoid of a gill, as in all the Teleostei, but even the fourth gill may disappear, and indeed only the second gill may be left, as in *Amphipnous*.

Sometimes, as in *Lepidosteus* and the Sharks, the hyoidean arch also supports a gill.

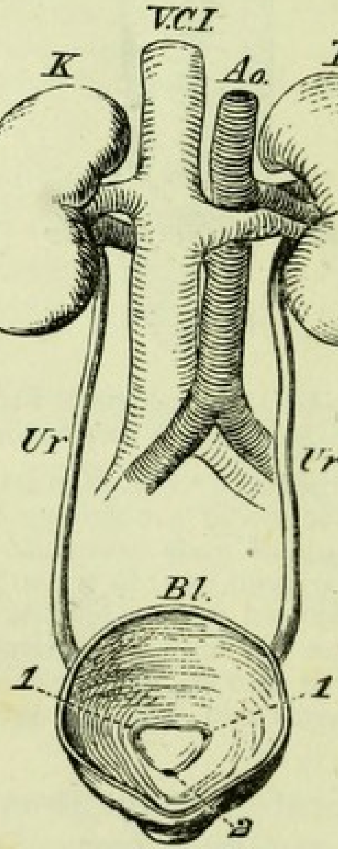

FIG. 406.

The kidneys (*K*); ureters (*Ur*); with the aorta (*Ao*), and vena cava inferior (*VCI*) and the renal arteries and veins. *Bl* is the bladder, the top of which is cu off so as to show the openings of the ureters (1, 1) and that of the urethra (2).

9. The general appearance, position, structure, and func tion of the KIDNEYS in man have been already noticed ii

the Fifth Lesson of "Elementary Physiology," § 6. Here it may be added that the true kidneys are not the primitive urinary organs, but that the first-formed structures of this kind are what are called the *Woolffian bodies*—or primordial kidneys. These Woolffian bodies are formed one on each side of the line of attachment of the alimentary canal to the spine. They appear very early, each as a series of transversely extended tubuli, and on the outer side of each is a duct which extends post-axially and enters that primitive chamber at the hind end of the body (the *cloaca*) into which the termination of the alimentary canal also opens.

The kidneys arise behind the Woolffian bodies, and independently of them; and the ducts which pass from the kidneys (the *ureters*) also terminate, independently of the termination of the Woolffian ducts, in the same primitive chamber common to the alimentary and urinary systems.

The Woolffian bodies are gradually absorbed, and disappear as the kidneys become developed. The latter organs are at first smooth and oval, but soon become divided, each into about fifteen lobes. These subsequently coalesce, but even at birth the kidney shows signs on its surface of its previous lobulated condition.

10. In that man possesses distinct urinary or RENAL ORGANS, he agrees with all Vertebrates, with the single exception of the Lancelet, in which such parts have not been yet certainly determined.

In that Woolffian bodies are formed, man agrees with all other Vertebrates with the exception just referred to.

In that Woolffian bodies are subsequently replaced by true kidneys, man agrees with all Mammals and all Sauropsidans; but it may be that Woolffian bodies persist, and by themselves alone constitute the renal organs through the whole of life, in Ichthyopsidans.

The renal organ may exist as a very elongated body made up of a series of bodies analogous to Malpighian corpuscles,[1] connected at short intervals, as in the Myxinoids.

The urinary gland may extend on each side from the head to the opposite end of the abdominal cavity, as in the Sturgeon, and the ureters may join together before their termination, as in the same last-mentioned animal.

The two urinary glands may blend together behind the pharynx, as in many osseous Fishes; or at their posterior

[1] For a description of these corpuscles see the Fifth Lesson of "Elementary Physiology," § 9, Fig. 27.

end, as in *Proteus;* or for their entire length, as in the Spoonbill.

Their surface may be marked by convolutions like that of the human cerebrum, as in Sharks and Chelonians.

The opening of the ureters may be placed behind the posterior termination of the alimentary canal. This is the case in osseous Fishes, and consequently a true bladder must be wanting in them. Each ureter may, however, dilate into a large bladder-like structure, as in *Amia*, or there may be a single, median vesicle. It is possible for several distinct urinary ducts to open into this vesicle, as in the Stickleback.

Every sort of bladder-like structure may be absent, as in *Cobitis*, and in all Serpents and Birds. A true bladder may, however, be developed in Ichthyopsidans, as in the Batrachia, where it is placed in front of the termination of the alimentary tube and of that common chamber (the cloaca) into which that tube opens, as well as the bladder or renal ducts.

The right renal organ may be much longer and placed more forward than the left, as in Serpents.

The ureters may open, not into the bladder, but into the cloaca, as is the case in the Monotremes, or *Ornithodelphia*, and in Reptiles.

These ducts may terminate (in the cloaca) behind the alimentary canal, or may come rather to the side, and in the *Ornithodelphia* rather towards the front of the cloacal chamber.

These circumstances may serve to explain the difference between the position of the alimentary and urinary outlets in man's class, and the situation of those apertures in osseous Fishes where the alimentary outlet is anterior. The modification by which the urinary outlet comes to be anterior does not result from any change in the position of the termination of the alimentary tube, but in the gradual production forwards, on each side of it, of the ureters, till they come in non-Ornithodelphous Mammals to end (through the intervention of the bladder and urethra) in a canal opening altogether in front of the rectal aperture.

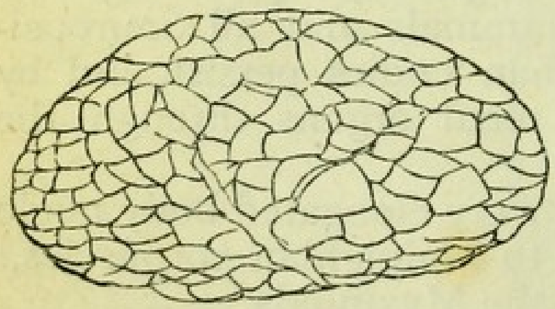

FIG. 407.—KIDNEY OF THE SEAL (*Phoca*), showing its lobulated condition.

The kidneys may be more symmetrical in position than in man. This is the case in most Birds, where they are imbedded in the depressions of the under surface of the sacrum, which is so expanded in the entire class *Aves*.

A condition of the kidneys analogous to that which at an early period exists in man, may not only persist throughout life in other animals, but may be much more complete, as in the Seals and Cetacea, where the kidneys are so divided into small lobes as to resemble a bunch of grapes. As many as 200 lobes have been counted in the Dolphin's kidney.

11. Two small glandular bodies, of unknown function, called SUPRA-RENAL CAPSULES, are placed one on the summit of each kidney. Each capsule is a flattened, triangular body, and shaped something like a cocked hat. It is formed of cellular tissue, often mixed with much fat, and provided with a fibrous coat which sends processes into the interior of the gland, these processes accompanying blood-vessels and nerves, which are numerous.

These organs exist in all the members of man's class, and in a general way resemble his in position and form. They are relatively largest in Rodents, as in the Coypu and Porcupine, where they are cylindrical in form.

They are relatively smallest in the Cetacea amongst Mammals, where, as also in Seals, they exhibit a lobulated exterior like that of the kidney itself.

In Birds these organs are relatively smaller, being in the Goose only about the size of a pea. They also vary more in shape in Birds than in man's class, and sometimes become confluent. They are usually, in Birds, placed on the inner side of the kidneys.

The supra-renal capsules may be in the form of a single, elongated, narrow, lobulated body, situate behind the renal organ, as mostly in Sharks; or may appear as a yellow streak on the ventral aspect of the urinary gland, as in the Frog and Toad.

Each supra-renal capsule may be divided into a greater or less number of lobules, as in some Urodeles, the Sturgeon, and many Fishes.

12. The SPLEEN of man has been noticed in the Fifth Lesson of "Elementary Physiology," § 28. It is a ductless body, of irregular and variable shape, richly supplied with blood-vessels, and lying beneath the diaphragm at the cardiac end of the stomach.

In the possession of a spleen man agrees with all other Vertebrata, with the exception of the Lancelet, and possibly also with the exception of the *Marsipobranchii*, *Lepidosiren*, and *Ceratodus*.

This organ may be relatively much larger than in man, and consist of two lobes, as in the Ornithorhynchus; it may consist of three lobes, as in the Echidna. Occasionally in Rodents a small detached accessory spleen may be developed, and there are constantly accessory spleens in the Sturgeon, the Dolphin, and Narwhal.

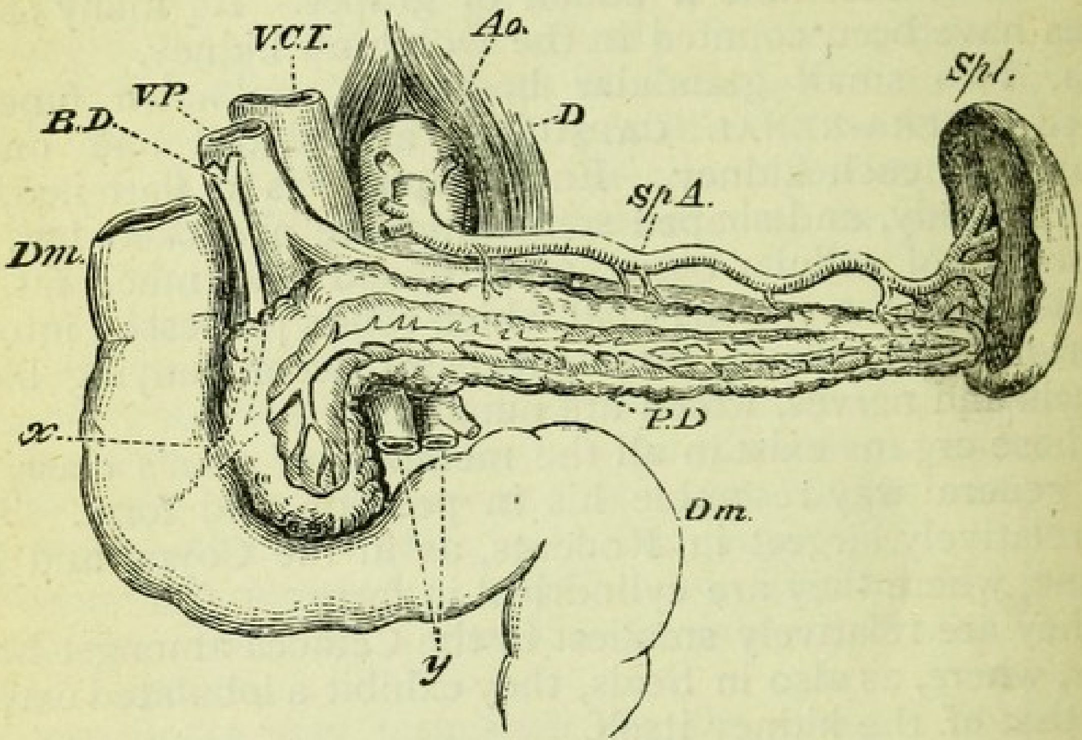

FIG. 408.—THE SPLEEN (*Spl.*) with the splenic artery (*SpA*). Below this latter is seen the splenic vein running to help to form the *vena portæ* (*VP*).

Ao, the aorta; *D*, a pillar of the diaphragm; *PD*, the pancreatic duct exposed by dissection in the substance of the pancreas; *Dm*, duodenum; *BD*, the biliary duct opening into the pancreatic duct at *x*; *y*, the intestinal vessels.

13. The THYROID GLAND of man is a soft, reddish, and very vascular body, embracing the trachea in front, and ascending to the larynx. It has no duct, and is of a more or less semilunar form, with two *lateral lobes*, united by an *isthmus*. It is covered by the sterno-hyoid, sterno-thyroid, and omo-hyoid muscles.

In that man develops a thyroid gland he appears to agree with all Vertebrates except the Lancelet.

This body may consist of two completely divided lateral halves, placed each on one side of the trachea and larynx, as in Birds, Batrachians, Monitors, the Llama, the Otter, the Mole, and others, and as even in the Orang. It may consist of one undivided body, as in Cetaceans.

It may be represented (as in Birds) by small rounded or elongated bodies, very vascular, placed beside the trachea, above the syrinx, and closely connected with the carotid or vertebral artery, or both. It may lie between the diverging carotids, as in *Python* and *Chelonia*, or on the carotids, close to the basi-branchials, as in the Frog. It is thus generally connected with the primitive arteries to which the aorta gives rise.

14. The THYMUS GLAND of man is but a temporary structure, which disappears in the adult, and is at its maximum of size at about the end of the second year. It is then long and narrow, and placed partly in the chest and partly in the neck (between the sternum and the great vessels), and having the appearance of a ductless gland. It is irregular in shape, with a considerable internal cavity, but it is more or less completely divided into two elongated *lateral lobes*, which taper upwards. At birth it measures about two inches in length.

In that man develops a thymus gland he agrees with air-breathing Vertebrates generally.

It appears to be wanting in *Proteus* and *Siren*, and to be developed in the Tadpole of the Frog only with the development of the lungs, disappearing again in the adult, and being transformed into fat. It is often, as in the Frog, a double gland—one on each side. In the Chick the thymus soon aborts, but is present, when the animal is a week old, as two hollow tubes placed one on each side of the neck.

The thymus may be broad and flat, covering the thyroid sternally, as in Iguana. It may send up, on each side, a process within the angle of the mandible, and may so form a large mass beneath the skull, as in the Calf.

15. The CUTANEOUS GLANDS of the human body are insignificant in size, with the exception of that special agglomeration of them which constitutes the MAMMARY GLAND, or breast.

They are of two kinds—*sebaceous glands* and *sudoriferous* or *sweat glands.*

(1) The sebaceous glands (noticed in Lesson V. § 32 of the "Elementary Physiology") are each a cluster of small secreting tubes placed in the dermis, and discharging their fatty secretion, by a small duct, usually into the sheath or follicle of one of the hairs.

(2) The sudoriferous glands (noticed in Lesson V. §16 of the "Elementary Physiology") consist each of a fine secreting tube, coiled up into a ball, placed beneath the dermis, in the subcutaneous tissue, and pouring out its contents by a delicate convoluted tube opening by a pore on the surface of the epidermis.

They are placed in different degrees of proximity on different parts of the body; and it is said that there may be 400 or 600 in a square inch of the skin of the back, or even 2,800 in a square inch of the palm of the hand.

In size they may be about $\frac{1}{72}$ of an inch in diameter, but they may also attain to one-sixth of an inch in the axilla, or armpit.

In man there are no great special aggregations of cutaneous glands in certain regions, but we find many and various such aggregations in species of his own class.

Thus there may be an aggregation of such glands opening into an inverted fold of skin in front of the eye, as in

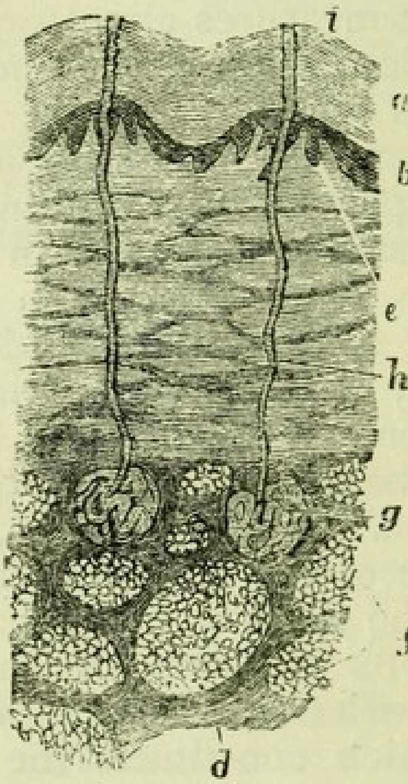

FIG. 409.—SECTION OF THE SKIN, SHOWING THE SWEAT GLANDS.

a, the epidermis; *b*, its deeper layer, the *rete Malpighii*; *e*, *d*, the dermis, or true skin; *f*, fat cells; *g*, the coiled end of a sweat gland; *h*, its duct; *i*, its opening on the surface of the epidermis.

many Ruminants, *e.g.* the Indian Antelope and the Deer, where the gland opens externally in a fissure near the front angle of the eye, and is lodged in the lachrymal fossa before referred to in Lesson III. § 28, p. 118.

A similar structure may be placed in the occiput, as in the Camel, or behind the ear, as in the Chamois.

There may be a large gland in the temporal region opening between the eye and the ear, as in the Elephant.

There may be a series of glandular structures on each flank, as in the Shrews ; or there may be a glandular sac opening near the armpit, as in the Bat *Cheiromeles*.

There may be a gland in the sacral region of the back, opening by a median orifice like a dorsal navel, as in the Peccari.

There may be a gland in each groin, as in the Corinne Antelope, or placed more medianly and post-axially, as in the Musk Deer, where the sac may be three inches broad.

Scent-glands may open at or near the post-axial termination of the intestine, as in many Carnivora, *e.g.* the Skunk and Hyæna. In the higher division of man's order (the Apes) there are no such glandular structures, but in the Lemuroids (e.g. *Cheiromys*) there may be a shallow pit-like gland on each side of the end of the alimentary tube.

There may be a scent-gland in the tail, as in the Desman and the Fox, or near the arm, as in certain Bats (*Emballonura* and *Saccopteryx*), where there is a glandular sac in each wing-membrane.

A glandular structure may open behind the foot, as in the Rhinoceros, or in front of it, between the toes, as in the Sheep.

We may find (as in the male Ornithorhynchus and Echidna) a large gland placed in the leg, and furnished with a long duct which passes to the heel and there traverses a perforated spur like the poison-fang of a Serpent, though it does not seem to poison, or even to be used for defence.

In descending below man's class to Birds, we find a peculiar cutaneous structure, the "*uropygial gland*," consisting of two parts conjoined, and in the Swan measuring an inch and a half in length. It is placed upon the more post-axial caudal vertebræ and ploughshare bone, and opens on the skin, where it discharges a greasy fluid to lubricate the feathers.

Another glandular structure is present in Birds, the *Bursa Fabricii*. This is a conical cavity which opens into the post-axial region of the cloaca. It is placed between the ureters, on the ventral aspect of the sacrum.

In Reptiles we may find other structures. Thus there may be, as in the Crocodile, a musky gland inside the mandible ; or beneath it, as in the Indian Tortoise. There may be a glandular fossa opening into the dorsal aspect of the cloaca, as in the Terrapins ; or a pair of elongated sacs opening beside the post-axial termination of the intestine, as in the common Snake ; or a pair of glandular depressions of the skin placed one on each side between the eye and the nose, as in *Crotalus*.

There may be a series of glands in each thigh, with a row of conspicuous openings, called *femoral pores*, on its inner surface, as in very many Lizards (*Lacerta*, *Monitor*, &c.), or in the armpit, as in *Iguana*, or in front of the cloacal opening, as in *Hysteropus*.

We may find (*e.g.* in the Chameleon) cutaneous structures termed *chromatophores*, which are little sacs containing pigment of various colours, and each with an aperture which, when open, allows the colour contained to appear, and when closed conceals it. It is by the various contractions of these sacs that the Chameleon effects those changes of colour for which it is celebrated.

It is in the next lower class, Batrachia, that we find the cutaneous glands carried relatively to their maximum of development.

They may be aggregated in a mass behind the eye and above the tympanum on each side, forming the so-called "parotoid" glands, as in the common Toad.

There may be a similar structure on the arms, as in *Pelobates*, or on the upper side of the leg, as in *Bufo Calamita*. The whole skin of the back may be of this nature, as in *Kalophrynus*, or these glands may be localised in two longitudinal series, as in *Salamandra*, where they extend from the head to the end of the tail. Their secretion may be more or less acrid, as in the last-named genus and in the Toad.

It is not certain that true cutaneous glands, homologous with those of higher Vertebrates, exist in the class of Fishes. This is remarkable, seeing the very great development they attain in the Batrachian class of Ichthyopsidans.

Nevertheless, a copious mucus exists on the skin in Fishes, and notably in the Eel. This escapes from the deeper structures through minute orifices, but is by some naturalists considered to be rather itself a modified epidermis than a true cutaneous secretion.

In most Fishes there is a complex system of special canals, the nature of which has been commonly deemed excretory, but is now considered to be rather sensory in function. These canals are usually disposed symmetrically, and are filled with a clear gelatinous substance. They constitute the "lateral line," the passage of which modifies and marks the scales it traverses, and is thus useful in zoological classification—the lateral line forming a more or less conspicuous mark running antero-posteriorly along each side of the body and tail of most Fishes.

That special modification of the cutaneous glands called the MAMMARY GLAND, or breast, is peculiar to man's class, which from this circumstance alone bears the name of *Mammalia*.

These glands may be devoid of a nipple, as is the case in the Ornithorhynchus and Echidna, or the nipples may be very long, as in Marsupials. There may be as many as twenty-two glands, as sometimes in *Centetes;* or ten, as in the Hedgehog and domestic Sow.

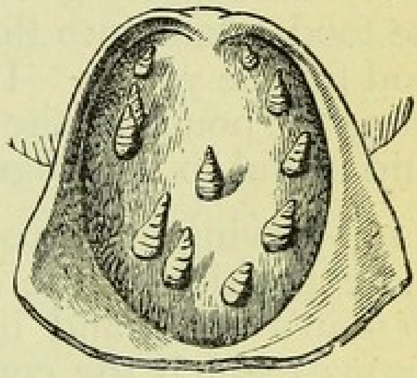

FIG. 410.—MARSUPIAL POUCH OF AN OPOSSUM (*Didelphys cancrivora*), cut open to the eleven nipples within—one of these eleven teats being median in position.

There is never one nipple only, though very rarely their number may be odd, as in some Opossums.

The glands may open into a little depression, or sac, formed during their functional activity, as in the Echidna.

They may be placed inside a permanent cutaneous pouch, as in Marsupials.

In that group there may be four nipples, as in the Kangaroo; or eight arranged in a circle, as in *Phascopale penicillata;* or four on each side and one in the middle, as in *Didelphys dorsigera;* or six on each side and one in the middle, as in the Virginian Opossum.

These glands may be placed nearer the middle line of the back than that of the belly, as in the aquatic Coypu Rat; or near the armpit, as in *Pteropus.*

There may be two pectoral mammæ in animals remote from man's order, as in the Elephant, Sloths, and Sirenia.

The Sirenia from this circumstance, together with their rounded heads and fish-like tail, probably gave rise to the belief in the existence of Mermaids.

There may be but two mammary glands, each opening in a depression and placed quite at the hinder end of the belly, as in Cetaceans.

In Ruminants we have posteriorly situate glands with teats forming an "udder."

In man's own order we find, in the Ape, but two pectoral mammæ; but amongst the Lemuroids there may be only a pair of ventral (inguinal) glands, as in *Cheiromys;* or a pair of inguinal and also a pair of pectoral ones, as in *Tarsius;* or two pairs of pectoral mammary glands, as in *Galago.*

Each teat is traversed by a single efferent canal in Ruminants, Pigs, and Cetaceans; by two in Horses and Apes; by five or six in some Rodents and Carnivora; and by more in the Elephant, Sirenia, Marsupials, and higher Primates.

As has been said, mammary glands are confined to man's class: the only faint adumbration of such organs, outside his class, is to be found in Pigeons, where the crop secretes a milky fluid (during the breeding season) which mixes with the food taken into that receptacle—the mixture serving as food for the young. It has also been asserted that glands lining the pouch of the Fish *Hippocampus* secrete a nutritious fluid useful to its progeny.

16. Having now completed our elementary investigation and exposition of the various organs and parts which make up man's body, and having noted the more important differences which the corresponding structures may present in other Vertebrate animals, it may be well shortly to recapitulate some of the leading distinctions in a different sequence and arrangement, in order to bring out more clearly not only the peculiarities, but also the affinities evidenced by various anatomical relations between the body of man and those of other Vertebrates.

In the first place MAN differs from the entire class of FISHES in the following points:—

(1) He has a skeleton the appendicular parts of which are divided into upper-arm, fore-arm and hand, and thigh, leg, and foot, respectively.
(2) His hyoid is a small structure with one pair of cornua instead of several branchial arches.
(3) His skull is formed with a large basi-sphenoid but no para-sphenoid; with a large squamosal confluent with a "petrous bone;" and with a mandible formed of two united pieces directly suspended from the squamosal.
(4) His auditory ossicles are minute, and take no part in suspending the mandible.
(5) His ribs, articulated dorsally by head and tubercle, are connected on the ventral side with a sternum.
(6) His vertebræ have at first terminal epiphyses.
(7) He has a pelvis formed of two ilia, two ischia, and two pubes united dorsally to a sacrum.

(8) His coccygeal region is rudimentary.
(9) His skin is furnished with hair.
(10) The muscles of his limbs are numerous and complex.
(11) His cerebrum is excessively large, with a corpus callosum, and his corpora quadrigemina are very small.
(12) He has distinct hypoglossal nerves, which perforate the occipital.
(13) His olfactory nerves traverse a cribriform plate.
(14) His ear has a spiral cochlea, a tympanic membrane, and an Eustachian tube.
(15) His posterior nares open far back within the mouth.
(16) His tongue is large and fleshy.
(17) He never has gills at any time of life.
(18) He breathes by lungs from his birth.
(19) His heart has two auricles and two ventricles.
(20) All the blood of his body passes through the lungs.
(21) There is no communication, in the adult, between the veins and arteries, save by the capillaries.
(22) He has but one aortic arch.
(23) He is furnished with a larynx.
(24) His alimentary canal neither terminates in a cloaca nor anteriorly to the urinary outlet.
(25) He has a complete diaphragm.
(26) His kidneys replace transitory Woolffian bodies.
(27) He has no fin rays.
(28) His blood-corpuscles are not nucleated.
(29) He is provided with salivary glands.

17. Man is distinguished from all BATRACHIANS in that—

(1) His skull is formed with a large basi-sphenoid but no para-sphenoid, with a large squamosal confluent with a "petrous bone," and a mandible formed of two united pieces directly suspended from the squamosal.
(2) His skull has a well-developed basi-occipital.
(3) His auditory ossicles are minute, and take no part in suspending the mandible.
(4) His ribs join a sternum.
(5) His vertebræ at first have terminal epiphyses.
(6) His skin is furnished with hair.
(7) His cerebrum is excessively large, with a corpus callosum, and his corpora quadrigemina are very small.
(8) His olfactory nerves traverse a cribriform plate.
(9) His ear has a spiral cochlea.
(10) His posterior nares open far back within the mouth.

(11) He never has gills at any time of life.
(12) His heart has two ventricles.
(13) All the blood of his body passes through the lungs.
(14) There is no communication, in the adult, between the veins and arteries, save by the capillaries.
(15) He has but one aortic arch.
(16) His alimentary canal does not terminate in a cloaca.
(17) He has a complete diaphragm.
(18) His kidneys replace transitory Woolffian bodies.
(19) His blood-corpuscles are not nucleated.
(20) He is provided with true salivary glands.

18. Man is distinguished from REPTILES in that—

(1) His skull has a "petrous bone" and a mandible formed of two united pieces directly suspended from the squamosal.
(2) His auditory ossicles are minute, and take no part in suspending the mandible.
(3) His vertebræ at first have terminal epiphyses.
(4) His skin is furnished with hair.
(5) His cerebrum is excessively large, with a corpus callosum, and his corpora quadrigemina are very small
(6) His olfactory nerves traverse a cribriform plate.
(7) His ear has a spiral cochlea.
(8) All the blood of his body passes through the lungs.
(9) There is no communication, in the adult, between the veins and arteries, save by the capillaries.
(10) He has but one aortic arch.
(11) His alimentary canal does not terminate in a cloaca.
(12) He has a complete diaphragm.
(13) The whole tarsus moves freely on the tibia, and there is no intertarsal joint.

Man also differs from all Reptiles except the Crocodilia in that—

(14) His blood-corpuscles are not nucleated.
(15) His heart is provided with two completely distinct ventricles.
(16) His posterior nares open far back within the mouth.

19. Man is distinguished from BIRDS in that—

(1) His skull has a "petrous bone" and a mandible formed of two united pieces directly suspended from the squamosal.

(2) His auditory ossicles are minute, and take no part in suspending the mandible.
(3) His vertebræ at first have terminal epiphyses.
(4) His skin is furnished with hair, and is devoid of feathers.
(5) His cerebrum is excessively large, and with a corpus callosum, and his corpora quadrigemina are very small and not placed laterally and depressed.
(6) His olfactory nerves traverse a cribriform plate.
(7) His ear has a complex spiral cochlea.
(8) His solitary aortic arch arches over the left bronchus.
(9) No air-cells communicate with the lungs.
(10) He has no syrinx, but a large and complex larynx.
(11) His lungs are freely suspended in the thoracic cavity.
(12) His alimentary canal does not terminate in a cloaca.
(13) His ureters open into the bladder.
(14) He has a complete diaphragm.
(15) His posterior nares open far back within the mouth.
(16) His coracoids are small processes.
(17) His ulna is larger than his radius.
(18) His hand has five digits and nine carpal bones.
(19) His pelvis unites with the sacrum only, and not with lumbar and dorsal vertebræ, and has its acetabula imperforate.
(20) His fibula is free at its lower end.
(21) His tarsus does not unite partly with the tibia and partly with the metatarsus, and form an intertarsal joint.
(22) He has five digits to his foot.
(23) His coccyx does not terminate in a ploughshare bone.
(24) He is furnished with teeth.
(25) His blood-corpuscles are not nucleated.

20. Man differs from the MONOTREMES in that—

(1) His vertebræ at first have terminal epiphyses.
(2) His cerebrum has a very large corpus callosum and small anterior commissure.
(3) His ear has a complex spiral cochlea.
(4) His alimentary canal does not terminate in a cloaca.
(5) His ureters open into the bladder.
(6) His coracoids are small processes, and he has no epicoracoids or large interclavicle.
(7) His acetabula are imperforate.
(8) He has no marsupial bones.
(9) His fibula has no upper olecranon-like process.

(10) He has definite calcareous teeth.
(11) The mammary glands are provided with nipples.

21. Man differs from all MARSUPIALS in that—

(1) His cerebrum has a very large corpus callosum and a small anterior commissure.
(2) He has no marsupial bones.
(3) The angle of his mandible is not inflected.
(4) His internal carotid perforates the petrous bone, and not the sphenoid.

22. Man is distinguished from all MAMMALS below his own order in that—

(1) His anterior extremities are provided with thumbs.
(2) His orbits are separated off from the temporal fossæ by bony lamellæ.
(3) His dental formula is I $\frac{2}{2}$, C $\frac{1}{1}$, P M $\frac{2}{2}$, M $\frac{3}{3}$.

23. Man differs from all MEMBERS OF HIS ORDER except the three highest genera, the Orang (*Simia*), the Gorilla and Chimpanzee (*Troglodytes*), and the Gibbons (*Hylobates*), in that—

(1) His sternum is of considerable breadth.
(2) His metapophyses and anapophyses are very little developed.
(3) His cerebrum is richly convoluted.
(4) His cæcum has a vermiform appendix.
(5) His hallux is not formed for grasping, but for supporting his body in an erect posture.

24. Man differs from even the HIGHEST APES in—

(1) The position of his body being erect.
(2) The curvature of his spine and the form of his pelvis being consequently peculiar.
(3) That his thumb reaches to the middle of the proximal phalanx of the index.
(4) His femur being longer absolutely, its shaft more angular, and its linea aspera more projecting.
(5) The absolute length of his tibia and the sharpness of the crest of that bone.
(6) The descent of the posterior border of the distal articular surface of the tibia below its anterior border.
(7) The much greater descent of the peroneal than of the tibial malleolus.

(8) The shortness of the foot compared with the length of the pelvic limb minus the foot, and compared with that of the tibia.
(9) The great breadth of the lowest part of the tuberosity of the os calcis.
(10) The flattened surface, for the hallux, of the ento-cuneiform bone.
(11) The fact of the first or second digit being the longest one of the foot.
(12) The absolute size of the hallux, and especially of its second phalanx.
(13) The very slight outward direction of the great toe (which is not prehensile) and the great proportion borne by it to the longest digit.
(14) The small proportion borne by the four outer digits of the foot to the whole foot and to the metatarsal bones.
(15) The successive decrease in length of the tarsus, metatarsus, and digits.
(16) That the cervical spines, above the seventh, are short and usually bifurcate.
(17) The occipital condyles being more anteriorly situate on the basis cranii.
(18) That the cranio-facial angle varies from 90° to 120°.
(19) The cerebral cavity being more than $2\frac{1}{4}$ times the length of the basi-cranial axis.
(20) That the superciliary ridges are little developed.
(21) That the maxillo-premaxillary suture is not visible on the face of the skull, even at birth.
(22) That he has a nasal spine.
(23) The distance between the zygomata, where widest, exceeding but little the greatest transverse diameter of the bony brain-case.
(24) That there is a large vaginal ridge to the petrous bone, and a long styloid process.
(25) That his jaws are relatively small.
(26) That hair is very little developed on the surface of the body, and is deficient on the back, though ordinarily abundant on the head.
(27) That there is an *extensor primi internodii pollicis* muscle, and also a *peroneus tertius*.
(28) The *flexor pollicis longus* and the *flexor longus digitorum perforans* being completely separate.
(29) That the *soleus* has a tibial as well as a fibular origin.

(30) That all four heads of the *flexor brevis digitorum pedis* arise from the os calcis.
(31) That the fibular interosseous muscle of the second toe of the foot arises from the middle metatarsal on the dorsal side of the tibial interosseous muscle of the middle toe.
(32) The absolute size of the brain.
(33) The greater complexity and less symmetrical disposition of its convolutions.
(34) The smallness of the canines and the absence of an interspace between them and the adjoining teeth.
(35) That the permanent canine is cut before the second true molar teeth.

25. A perusal of the list of characters given in the nine preceding paragraphs must manifest to the beginner in anatomy how small and insignificant are the characters which separate man's structure from that of other members of his class, compared with those which distinguish him from Birds and other yet inferior groups.

Viewed from the anatomical standpoint, man is but one species of the order Primates; and he even differs far less from the higher Apes than do these latter from the inferior forms of the order.

This work being purely anatomical, it is only needful here to remind the reader—of what common sense teaches us—that to estimate any object *as a whole*, its powers of action no less than its structure must be taken into consideration.

The structure of the highest plants is more complex than is that of the lowest animals; but for all that, powers are possessed by jelly-fishes of which oaks and cedars are devoid.

The self-conscious intelligence of man establishes between him and all other animals a distinction far wider than the mere superiority of his brain, in mass and complexity, or any other physical difference, would indicate.

All, however, who admit the idea of man's moral responsibility are logically compelled to go much further, and to confess that in this respect he is separated from the rest of the visible creation by an abyss so vast that no chasm separating the other kingdoms of nature from one another can be compared with it.

Evident, then, as it is from the teaching of anatomy that the various parts of the human body have a classificatory value indicating the zoological position of the whole structure, it is no less evident from other considerations, that to allow mere anatomy to warp our judgment as to the TOTALITY OF MAN'S NATURE would be a serious mistake.

To estimate correctly an existence of which mind forms a part, recourse must be had to Philosophy, and especially to Psychology. Unlike physical science, Philosophy is not restricted to the interpretation of existences belonging to one sphere only, but seeks to investigate all orders of truth and every kind of existence which is capable of apprehension by the mind of man.

INDEX.

Each animal, the zoological position of which has not been given in the First Lesson, has the title of the group to which it belongs placed (between brackets) after its name.

E.

Q.

R.

S.

THE END.

LONDON:
R. CLAY, SONS, AND TAYLOR, PRINTERS,
BREAD STREET HILL.