ON

THE ARCHETYPE AND HOMOLOGIES

OF

THE VERTEBRATE SKELETON.

BY

RICHARD OWEN, F.R.S.

LONDON:
PRINTED FOR THE AUTHOR,
BY RICHARD AND JOHN E. TAYLOR,
RED LION COURT, FLEET STREET.
1848.

TO

WILLIAM JOHN BRODERIP, ESQ.,

F.R.S., F.G.S., F.L.S., &c.

My dear Broderip,

The interest which you have taken in the progress of the researches that are embodied in the present Treatise on the Vertebrate Archetype induces me to dedicate it to you: and I am happy in having this opportunity of gratefully acknowledging your excellent guidance by which my early studies in Zoology were facilitated, and of expressing the affection and esteem with which I am,

Your sincere Friend,

RICHARD OWEN.

ADVERTISEMENT.

The subject of the following Essay has occupied a portion of my attention from the period when, after having made a certain progress in Comparative Anatomy, the evidences of a greater conformity to type, especially in the bones of the head of the Vertebrate animals, than the immortal Cuvier had been willing to admit, began to enforce a reconsideration of his conclusions, to which I had previously yielded implicit assent. The results*, in so far as they seemed to be fairly sustained by observation of facts, have been successively communicated to the Royal College of Surgeons of England in my Hunterian Lectures for 1844 and subsequent years; and in 1846 I availed myself of the peculiar advantages afforded by the 'British Association for the Advancement of Science' to bring my general views on the Archetype and Homologies of the Vertebrate Skeleton before the British and Foreign Anatomists assembled at the meeting of the Association at Southampton, in order to submit them to the test of a discussion which could not have been so fully carried out under any other circumstances in this country, where Homological Anatomy had previously excited little

* Those illustrated by the skeleton of fishes are given in the 'Lectures on the Comparative Anatomy and Physiology of the Vertebrate Animals,' Part 1. 1846.

attention, and had remained almost in the state in which it was left by Cuvier and Geoffroy St. Hilaire.

The interest which has since been expressed on the subject of those communications, published as a 'Report' in the Transactions of the British Association for 1846, and the wish to make the matter of that 'Report' more accessible and intelligible to students of anatomy, have induced me to reprint it in a separate form, with some additional facts and illustrations.

I beg to express my obligations to the President and Council of the British Association for the permission to reprint the substance of my Report, and for the liberal use of the woodcuts with which it was illustrated. And I am glad here to have the opportunity to acknowledge the valuable aid which I derived from the skill and care and patience of Mr. Frederick Gyde, the wood-engraver, in rendering accurately the numerous details and references in the figures, and to express similar acknowledgements to Mr. Tuffen West, the lithographer of the plates.

CONTENTS.

CHAPTER I. SPECIAL HOMOLOGY.

CHAPTER II. GENERAL HOMOLOGY.

CHAPTER III. SERIAL HOMOLOGY.

ON

THE ARCHETYPE AND HOMOLOGIES

OF

'HE VERTEBRATE SKELETON.

CHAPTER I.—SPECIAL HOMOLOGY.

Introduction.

'HEN the structure of organized beings began to be investigated, the rts, as they were observed, were described under names or phrases suggested their forms, proportions, relative position, or likeness to some familiar ob-ct. Much of the nomenclature of human anatomy has thus arisen, espe-lly that of the osseous system, which, with the rest of man's frame, was idied originally from an insulated point of view, and irrespective of any ier animal structure or any common type.

So when the exigences of the veterinary surgeon, or the desire of the turalist to penetrate beneath the superficial characters of his favourite ss, led them to anatomise the lower animals, they, in like manner, seldom inced beyond their immediate subject, and often gave arbitrary names the parts which they detected. Thus the dissector of the horse, whose ention was more especially called to the leg as the most common seat disease in that animal, specified its 'cannon-bone,' its 'great' and 'small' stern-bones, its 'coffin-bone,' and its 'nut-bone' or 'coronet': some inial bones were also named agreeably with their shape, as the 'os qua-atum,' for example. The ornithotomist described, in the same irrelative inner, the 'ossa homoidea,' 'ossa communicantia' or 'interarticularia,' 'columella' and 'os furcatorium.' Petit* had his 'os grele' and 'os massue;' Herissant† his 'os carré'; which, however, is by no means the ne bone with the 'os carré' or 'os quadratum' of the hippotomist. The estigator of reptilian osteology described 'hatchet-bones' and chevron-nes, an 'os annulare' or 'os en ceinture,' and an 'os transversum': he ewise defined a 'columella'; but this was a bone quite distinct from that called in the bird. The ichthyotomist had also an 'os transversum,' which ain was distinct from that in reptiles, and he demonstrated his 'os discoi-um,' 'os cœnosteon,' 'os mystaceum,' 'ossa symplectica prima,' 'secunda,' rtia,' 'suprema,' 'postrema,' &c. Similar examples of arbitrary names might ily be multiplied; many distinct ones signifying the same part in different imals, whilst essentially distinct parts often received the same name from

* Observations Anatomiques sur les mouvemens du bec des Oiseaux, Mémoires de l'Acad. Sciences, 1748, p. 345.
† Mém. de l'Acad. des Sciences, 1774, p. 497.

different anatomical authors, occupied exclusively by particular specie Each, at the beginning, viewed his subject independently; and finding, there fore, new organs, created a new nomenclature for them; just as the anthro potomist had done, of necessity, when, with a view to the cure or relief o disease and injury, he entered upon the vast domain of anatomical science b the structure of Man, or of the mammals most resembling Man.

It may well be conceived with what a formidable load of names the me mory must have been burthened, if any could have been found equal to i had the anatomy of animals continued and made progress under its primitiv condition of an assemblage of arbitrarily described and uncompared facts.

Happily the natural tendency of the human mind to sort and generalize it ideas could not long permit such a state of the science, if science it could b called, to remain. A large and valuable portion of the labours of the com parative anatomists who have honoured the present century, has been devote to the determination of those bones in the lower animals which correspon with bones in the human skeleton; the results being usually expressed b applying to the parts so determined the same names, as far as the nomen clature of anthropotomy allowed. Few, however, of the parts of the huma body have received single substantive names; they are for the most part in dicated by shorter or longer descriptive phrases, like the species and parts o plants before Linnæus reformed botanical nomenclature.

The temptation to devise a systematic Nomenclature of Anatomy, generall applicable to all animals, increases with the advance of the science, and fro the analogy of what has taken place in other sciences it may one day b yielded to and exercise the ingenuity of some ardent reformer. But the sam analogy, especially that afforded by chemical science since the time of Lavo sier, would rather lead the true friend of anatomy to deprecate the attem to impose an entirely new nomenclature of parts, however closely expressiv of the nature and results of the science at the period when it might be devise For there is no stability in such descriptive or enunciative nomenclature; changes, and must change with the progress of the science, and thus becom a heavy tax upon such progress.

If the arbitrary term 'calomel,' which, like 'house' and 'dog,' signifies th thing in its totality, without forcing any particular quality of its subje prominently upon the mind, be preferable, on that account as well as it brevity, to the descriptive phrases 'submuriate of mercury,' 'chloride o mercury,' or 'proto-chloride of mercury,' in enunciating propositions respect ing the substance to which it is applied; and if it possesses the additional ad vantage of fixity, of a steady meaning not liable to be affected, like a descrip tive name or phrase, by every additional knowledge of the properties of th substance; the anatomist, zealous for the best interests of his science, will fe strongly the desirableness of retaining and securing for the subjects of hi propositions similar single, arbitrary terms, especially if they are also capabl of being inflected and used as noun adjectives.

The practice of anatomists of the soundest judgement has usually bee to transfer the anthropotomical term or phrase to the answerable part whe detected in other animals. The objection that the original descriptive o otherwise allusive meaning of the term seldom applies to the part with equ force in other animals, and sometimes not at all, is one of really little moment for the term borrowed from anthropotomy is soon understood in an arbitrar sense, and without regard to its applicability to the modified form whic the namesake of the human bone commonly assumes to suit the ends require in the lower species. No anatomist, for example, troubles himself with th question of the amount of resemblance to a crow's or other bird's beak in th 'coracoid' bone of a reptile, or with the want of likeness of the kangaroo

coccyx' to the beak of a cuckoo; or of the whale's 'vomer' to a plough-
are; or ever associates the idea of the original mystic allusion in the ana-
mical term 'sacrum' with his description of that bone in the megatherium
other monster. Common sense gratefully accepts such names when they
ecome as arbitrary as cat or calomel, and when such concretes or adjectives
'coccygeal,' 'vomerine' and 'sacral' can be employed to teach the pro-
rties or accidents of their subjects.

To substitute names for phrases is not only allowable, but I believe it to be dispensable to the right progress of anatomy; but such names must be arbi-ary, or, at least, should have no other signification than the homological one, anatomy, as the science of the structure of all animals, is to enjoy the inesti-able benefit of a steady and universal nomenclature. I am far from being in-nsible to the advantages which other sciences have derived from revolutions their technical language; but experience has also demonstrated attendant ils; and these, it is to be feared, would preponderate in the case of anatomy, account of the peculiar character of its origin, and the fact of its cultivators ing for the most part introduced to the science through the portal of anthro-otomy. So long, likewise, as due deference continues to be paid to the deep id vital importance of the practical applications of the parent science in edicine and surgery, it will be in vain for any man to expect that his sole thority would suffice for the general reception of an entirely new nomen-ature, however philosophically devised or clearly enunciative of the highest id most comprehensive truths of the science at the time of its formation.

After maturely considering this subject in its various relations, I have ar-ved at the conviction that the best interests of anatomical science will be nsulted by basing the nomenclature applicable to the vertebrate subking-om upon the terms and phrases in which the great anthropotomists of the 5th, 17th and 18th centuries have communicated to us the fruits of their mortal labours. For it is only on this firm foundation that we may hope avoid that ceaseless change of terms which follows the device of a syste-atic nomenclature significant of a given progress and result of scientific search. But the names of the parts of the vertebrate animals so based on deduced from the language of anthropotomy must divest themselves of eir original descriptive signification, and must stand simply and arbitra-ly as the signs of such parts, or at least with the sole additional meaning indicating the relation of the part in the lower animal to its namesake or omologue in Man. It is an old maxim accepted by the best logicians, that name is so good as that which signifies the total idea or whole subject, ithout calling prominently to mind any one particular quality, which is ereby apt to be deemed, undeservedly, more essential than the rest.

The chief improvement which the language of anatomy, based upon that anthropotomy, must receive in order to do its requisite duty, is the substi-tion of 'names' for 'phrases' and 'definitions'; and this is less a change nomenclature than the giving to anatomy what it did not before possess, it which is absolutely requisite to express briefly and clearly, and without eriphrasis, propositions respecting the parts of animal bodies. Such names ould be derived from a universal or dead language, and when anglicized, translated into other modern equivalents, ought to be capable of being flected adjectively.

A few examples will suffice to show how greatly the advantage of such ames preponderates over the trouble of substituting them in the memory r the definitions which previously signified the ideas.

In the classical Anthropotomy of Soemmerring, a well-defined part of the ull, which is a distinct bone in the human embryo, and permanently so in l cold-blooded Vertebrata, is called "pars occipitalis stricte sic dicta partis occipitalis ossis spheno-occipitalis*." Monro, in his justly-esteemed treatis 'On the Human Bones †,' defines the same bone as "all the part of the (oc cipital) bone above the great foramen." In the 'Elements of Anatomy,' b Dr. Quain ‡, a work of repute for its clearness and minuteness of detail, th part in question is neither named nor described. The term *supra-occipital* Lat. (*supra-occipital*, Eng., *sur-occipital*, Fr.), is obviously a gain to anatomica science in all propositions respecting this part in the vertebrate series.

Certain parts of a vertebra, distinct bones at an early period in man, an throughout life in most reptiles, are defined by Soemmerring as 'radices ar cûs posterioris vertebræ,' or 'arcus posterior vertebræ' collectively §. Monr describes the same parts separately, as "a broad oblique bony plate extende backwards," and together, as "a bony arch produced backwards": he names defines and minutely describes the processes, &c. of these bony plates, whicl in the series of Vertebrata are soon found to be non-essential characters; bu for the plates themselves, which are the most constant and essential consti tuents of a vertebra, he has no name. Dr. Quain defines the same parts as "tw plates of bone, the lamellæ or arches, which complete the central foramen ||." They are sometimes more briefly but vaguely spoken of in English work of Comparative Anatomy as "the vertebral lamellæ" or "vertebral laminæ," or "perivertebral elements." The term '*neurapophysis*,' Lat. and Eng. ('*neur apophyse*,' Fr.), applicable to each element individually, under which all it properties may be predicated of by the adjective 'neurapophysial,' withou periphrasis, seems by its adoption in the classical works of MM. Agassi and Stannius, to be as acceptable as the term 'sur-occipital' substituted b Cuvier for the definitions in anthropotomy above cited.

Similar instances of the absence of determinate names, capable of in flection, for parts of the human frame, will be seen in the last column o Table I., and others will occur to the anatomist, even in regard to mos important parts, as the primary natural divisions of the neural axis, fo example, to the great hindrance of brief, clear and intelligible descriptions So long as the phrases 'marrow of the spine,' 'chord of the spine,' continu to usurp the place of a proper name, all propositions concerning their sub ject must continue to be periphrastic, and often also dubious. Thus if th pathologist, speaking of diseases of the spinal marrow, desires to abbreviat his proposition by speaking of 'spinal disease,' he is liable to be misunder stood as referring to disease of the spinal or vertebral column. The vague but often-used phrase 'chorda dorsalis' for the embryonic fibro-gelatinous basis of the spine, adds another source of confusion likely to arise from th use of the term 'spinal chord,' as applied to that most important part of th neural axis which I have proposed to call 'Myelon ¶,' a term which, if adopted, would be attended by this advantage, that no ambiguity could arise in speak ing of 'myelonal functions,' 'myelonal affections,' or other properties of thi part of the central axis of the nervous system.

Anthropotomy, in respect to its nomenclature, or rather the want of one, is, as I have already remarked, not unlike what botany was before the time o Linnæus, and we may anticipate the happiest effects from a judiciously re formed technical language in the advancement of the true and philosophic knowledge of the human structure, from the rapid progress of botany when the opposition raised by sloth or envy to the Linnæan reforms was overcome. For a good general anatomical nomenclature, based and regulated upon the

* De Corporis Humani Fabrica, 1794, t. i. p. 162. † Kirby's edition, 8vo, 1820, p. 76.
‡ Elements of Descriptive and Practical Anatomy, 8vo, 1828, p. 50.
§ De Corporis Humani Fabrica, 1794, t. i. pp. 235, 236.
|| Elements of Descriptive and Practical Anatomy, 8vo, 1828, p. 121.
¶ Hunterian Lectures, vol. ii. 'Vertebrata,' part i. p. 172.

rineiples above defined, must reflect its benefits upon anthropotomy. I dare ot flatter myself that the names adopted or proposed for the Osseous System f the Vertebrata in my 'Hunterian Leetures' and in the first column of Table I. ill meet at onee with acceptance, but the attempt to establish such a nomenlaturc will be felt to have been an indispensable step in undertaking a general irvey of the homological relations of the vertebrate skeleton.

In proposing a definite name for each distinct bone, declaratory of its eeial homology throughout the vertebrate kingdom, I have sought earnestly reduce the amount of reform to the minimum allowed by the exigences the case. Agreeably with Aphorism III. of the 'Philosophy of the Inuetive Sciences' (p. lxvii.), the nomenclature of anthropotomy forms the isis, and all the names given to parts by one or other of the great French iatomists have been accepted, with the modifications of a Latin or an En-ish termination, wherever such names had not been applied, as is the case ith some proposed by Geoffroy St. Hilaire, to two different parts. In subituting names for phrases, I have endeavoured, conformably with another Dr. Whewell's canons (Aph. XVII. *op. cit.* p. cxvii.), to approximate the und of the name as nearly as possible to those of the leading terms of the finition or phrase, as e. g. *alisphenoid* for 'ala media, &c. sphenoidalis' and r 'grande aile du sphénoïde'; *orbitosphenoid* for 'ala superior seu orbilis, &c. sphenoidalis,' and for 'aile orbitaire du sphénoïde*.'

The corresponding parts in different animals being thus made namesakes, e called technically 'homologues.' The term is used by logicians as synomous with 'homonyms,' and by geometricians as signifying 'the sides of nilar figures which are opposite to equal and corresponding angles,' or to rts having the same proportions†: it appears to have been first applied in atomy by the philosophical cultivators of that science in Germany. Geofoy St. Hilaire says, "Les organes des sens sont *homologues*, comme s'eximerait la philosophie Allemande; c'est-à-dire qu'ils sont analogues dans ur mode de développement, s'il existe véritablement en eux un même prinpe de formation, une tendance uniforme à se répéter, à se reproduire de la ême façon‡." The French anatomist, however, seems not rightly to fine the sense in which the German philosophers have used the term: ere is a looseness in the expression 'analogous in their mode of developnt,' which may mean either identical or similar, and also different kinds of nilarity. Parts are homologous in the sense in which the term is used in is Work, which are not always similarly developed: thus the 'pars occitalis stricte sic dicta,' &c. of Soemmerring is the special homologue of the praoccipital bone of the cod, although it is developed out of pre-existing rtilage in the fish and out of aponeurotic membrane in the human subject. also regard the supraoccipital as the serial homologue of the parietal and midfrontal, although these are developed out of the epicranial membrane the fish, and not out of pre-existing cartilage, like the supraoccipital. e femur of the cow is not the less homologous with the femur of the crodile, because in the one it is developed from four separate ossific centres, and other from only one such centre. In like manner the compound mandilar ramus of the fish is the homologue of the simple mandibular ramus of

* The happy facility of combination which the German language enjoys has long enabled very eminent anatomists of that intellectual part of Europe to condense the definitions of hropotomy into single words; but these cannot become cosmopolitan; such terms as interhauptbeinkörper,' 'Schläfbeinschüppen,' and 'Zwischenkiemendeckelstück,' are likely be restricted to the anatomists of the country where the vocal powers have been trained m infancy to their utterance.

† This is the sense in which the term is defined in the French Dictionary and in our nson's Dictionary.

‡ Annales des Sciences Naturelles, tom. vi. 1825, p. 341.

the mammal, as the compound tympanic pedicle of the fish is homologou with the simple tympanic pedicle of the bird, the differences expressed b the terms 'simple' and 'compound' depending entirely on a difference o development.

Without knowing the precise sense in which Geoffroy St. Hilaire under stood 'analogous development,' one cannot determine how much or how littl it is applicable to the determination of homologies or to the definition o homologous parts. Dr. Reichert seems to have been unduly influenced by th idea of 'analogy or similarity of development in the determination of homo logous parts' when he rejected the parietal and frontal bones from the syster of the endo-skeleton, because they were not developed from a pre-existin cartilaginous basis*, or, because they could be easily detached from subja cent persistent cartilage in certain fishes; the essential distinction betwee these and the supra-occipital in regard to development being, that wherea the cartilaginous stage intervened in the latter between the membranous an the osseous stages, in the other, usually more expanded, cranial spines, th osseous change appears to be immediately superinduced upon the primitiv aponeurotic histological condition.

M. Agassiz seems, in like manner, to give undue importance to similarit of development in the determination of homologies, where he repudiates th general homology of the basi-sphenoid with the vertebral centrum, and cor sequently its serial homology with the basi-occipital, because the pointed en of the chorda dorsalis has not been traced further forwards along the basi of the cranium in the embryo osseous fish than the basi-occipital†. But th development of the centrum of every vertebra begins, not in the gelatinou chord, but in its aponeurotic capsule, and it is in the expanded aponeurosi directly continued from the 'chorda' along the 'basis cranii' that the thi stratum of cartilage-cells is formed from which the ossification of the bas sphenoid, presphenoid and vomer proceeds.

There exists doubtless a close general resemblance in the mode of deve lopment of homologous parts; but this is subject to modification, like th forms, proportions, functions and very substance of such parts, without thei essential homological relationships being thereby obliterated. These rela tionships are mainly, if not wholly, determined by the relative position an connection of the parts, and may exist independently of form, proportio substance, function and similarity of development. But the connection must be sought for at every period of development, and the changes of rela tive position, if any, during growth, must be compared with the connection which the part presents in the classes where vegetative repetition is greate and adaptive modification least.

Relations of homology are often not only confounded with those of analog but in some recent and highly estimable works on comparative anatomy th terms 'analogy' and 'analogue' continue to be used to express the ideas o homology and homologue, or are so used as to leave in doubt the meaning o the author. Thus when we read in the latest edition of the 'Leçons d'Ana tomie Comparée' of Cuvier, "Les branchies sont les poumons des animau absolument aquatiques," t. vii. p. 164; and with regard to the cartilagino or osseous supports of the gills, "elles sont, à notre avis, aux branchies de poissons, ce que les cerceaux cartilagineux ou osseux des voies aériennes son aux poumons des trois classes supérieures," *Ibid.* p. 177, we are left in doul whether it is meant that the gills and their mechanical supports merely perfor

* Vergleichende Entwickelungsgeschichte des Kopfes der nackten Reptilien, 4to, 183 pp. 212, 218.

† Recherches sur les Poissons Fossiles, 4to, 1843, i. p. 127.

ıe same function in fishes which the lungs and windpipe do in mammals, or ·hether they are not also actually the same parts differently modified in re- ıtion to the different respiratory media in the two classes of animals. The eeper-thinking Geoffroy leaves no doubt as to his meaning where he argues ı the 'Philosophie Anatomique' (8vo, 1818, 4ième mémoire, p. 205), that the rauchial arches of fishes are the modified tracheal rings of the air-breathing ertebrates: we perceive at once that he is enunciating a relation of homology.

I have elsewhere* discussed the relations, both homological and analogical, f the respiratory organs of the air-breathing and water-breathing vertebrate ıimals, and have here adverted to them merely to illustrate the essential ıstinction of those relations. In the 'Glossary' appended to the first volume ' my 'Hunterian Lectures,' the terms in question are defined as follows:—

"ANALOGUE."—A part or organ in one animal which has the same func- on as another part or organ in a different animal.

"HOMOLOGUE."—The same organ in different animals under every variety ' form and function†."

The little 'Draco volans' offers a good illustration of both relations. Its re-limbs being composed of essentially the same parts as the wings of a bird e homologous with them; but the parachute being composed of different ırts, yet performing the same function as the wings of a bird, is analogous them. Homologous parts are always, indeed, analogous parts in one sense, ıasmuch as, being repetitions of the same parts of the body, they bear in ıat respect the same relation to different animals. But homologous parts ay be, and often are, also analogous parts in a fuller sense, viz. as perform- ıg the same functions: thus the fin or pectoral limb of a Porpoise is homo- gous with that of a Fish, inasmuch as it is composed of the same or answerable ırts: and they are the analogues of each other, inasmuch as they have the me relation of subserviency to swimming. So, likewise, the pectoral fin of e flying-fish is analogous to the wing of the Bird, but, unlike the wing of e Dragon, it is also homologous with it.

Relations of homology are of three kinds: the first is that above defined, z. the correspondency of a part or organ, determined by its relative position ıd connections, with a part or organ in a different animal; the determination ' which homology indicates that such animals are constructed on a common pe: when, for example, the correspondence of the basilar process of the ıman occipital bone with the distinct bone called 'basi-occipital' in a fish crocodile is shown, the *special homology* of that process is determined.

A higher relation of homology is that in which a part or series of parts ands to the fundamental or general type, and its enunciation involves ıd implies a knowledge of the type on which a natural group of animals, e vertebrate for example, is constructed. Thus when the basilar process of e human occipital bone is determined to be the 'centrum' or 'body of the st cranial vertebra,' its *general homology* is enunciated.

If it be admitted that the general type of the vertebrate endo-skeleton is ghtly represented by the idea of a series of essentially similar segments ıcceeding each other longitudinally from one end of the body to the other, ıch segments being for the most part composed of pieces similar in number ıd arrangement, and though sometimes extremely modified for special func- ons, yet never so as to wholly mask their typical character,—then any ven part of one segment may be repeated in the rest of the series, just as ıe bone may be reproduced in the skeletons of different species, and this

* Lectures on Vertebrata, 1846, p. 279.

† Lectures on Invertebrate Animals, 8vo, 1843. Glossary, pp. 374, 379. My ingenious ıd learned friend Mr. Hugh Strickland has made a strong and able appeal to the good nse of comparative anatomists in favour of the restriction of these terms to the senses in hich they are here defined.—Phil. Mag. 1846, pp. 358, 362.

kind of repetition or representative relation in the segments of the san skeleton I call 'serial homology.' As, however, the parts can be namesak only in a general sense, as centrums, neurapophyses, ribs, &c.; and sin they must be distinguished by different special names according to their pa ticular modifications in the same skeleton, as *e. g.* mandible, coracoid, pub &c., I call such serially related or repeated parts 'homotypes.' The bas occipital is the homotype of the basi-sphenoid; or in other words, when tl basi-occipital is said to repeat in its vertebra or natural segment of the sk leton the basi-sphenoid or body of the parietal vertebra, or the bodies of tl atlas and succeeding vertebræ, its *serial homology* is indicated. The stu of this kind of homologies was commenced by Vicq d'Azyr, in his ingenio memoir 'On the Parallelism of the Fore and Hind Limbs.' If we exce the complex and extremely diversified and modified parts of the radiat appendages of the vertebral segments, to which Vicq d'Azyr restricted h comparisons, the serial homologies of the skeleton are necessarily demo strated when the general and special homologies have been determined.

In the present section I propose to consider some of those examples of sp cial homology which are least satisfactorily determined and respecting whi different opinions still sway different anatomists. Such instances are fort nately few, thanks to the persevering and successful labours of the great con parative anatomists of the last half-century: pre-eminent amongst whom w ever stand the name of CUVIER, in whose classical works, 'Ossemens Fossile 'Histoire des Poissons,' 'Leçons d'Anatomie Comparée' (posthumous edition and 'Règne Animal,' 1828, will be found the richest illustrations of the speci homological relations of the bones in the four classes of vertebrate animals.

Second only to CUVIER must be named GEOFFROY ST. HILAIRE, who memoir on the Bones of the Skull in Birds as compared with those in Mammal in the 'Annales du Muséum, t. x. (1807), forms an early and brilliant exampl of the quest of special homologies, which could not fail, with other and simil investigations of the same ingenious author, to impart a stimulus to th philosophical department of anatomical inquiry*. In regard to the osteolog of the crocodile, we find Cuvier and Geoffroy engaged in a long parallel seri of rival researches, the results of which have had the happiest effects in de termining some of the most difficult questions of special homology.

Nor was the co-operation of zealous cultivators of comparative anatom wanting in the eminent schools and universities of Germany. GOETHE, i deed, had taken the lead in inquiries of this nature in his determination, in 178 of the special homology of that anterior part of the human upper maxillar bone which is separated by a more or less extensive suture from the rest c the bone in the fœtus; and the philosophical principles propounded in th great poet's famous anatomical essays called forth the valuable labours of th kindred spirits, OKEN, BOJANUS, MECKEL, CARUS, and other eminent culti vators of anatomical philosophy in Germany.

It is not requisite for the purpose I have in view, to trace step by step th progress of the special homological department of anatomy. Its presen state, as regards the skull of the Vertebrata, will be best exposed by the vie of the fruits of the latest inquiries embodied in TABLE I. appended to thi Work.

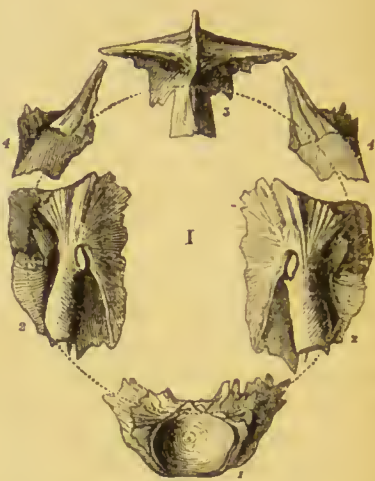
That table gives at one view the general results of the researches int the conformity of structure of the skull throughout the vertebrate serie

* Oken's famous "Programm, Über die Bedeutung der Schädelknochen" was publishe in the same year (1807) as Geoffroy's Memoir on the Bird's skull; but it is devoted less t the determination of 'special' than of 'general homologies': it has, in fact, a much highe aim than the contemporary publication of the French anatomist, in which we seek in vai for any glimpse of those higher relations of the bones of the skull, the discovery of whic has conferred immortality on the name of OKEN.

by the two great French anatomists who have most advanced this part of osteological science; by the authors of two classical German works on Comparative Anatomy; and by their countryman Dr. Hallmann, who has detailed in an elaborate treatise his especial investigations of some of the most difficult parts of this difficult inquiry. I have added the synonyms of the bones of the head of fishes from the great work of the celebrated Swiss naturalist, who has, so happily for ichthyology, devoted himself to the advancement of that interesting branch of Natural History; and also, the anthropotomical terms for the corresponding parts in the human skeleton. These, after much comparison and deliberation, I have chosen from the justly-celebrated work of SOEMMERRING, the high reputation of which has been sanctioned by the new edition to which some of the most eminent of the German professors of anthropotomy and physiology have recently devoted their combined labours. The English teacher of these sciences will find some of the descriptive designations of the parts by Soemmerring not agreeing with those which he may be in the habit of using, and which are current in the later Manuals of Anthropotomy published in this country: the 'ossa lateralia lingualia' are more commonly called, with us, the 'cornua majora ossis hyoidei'; the 'os spheno-occipitale' is generally described as two distinct bones, the 'os occipitis' and 'os sphenoide'; the 'pars occipitalis stricte sic dicta,' &c. is sometimes called 'squama occipitalis,' or occipital plate; and other synonyms might easily be multiplied from the osteological treatises of Monro and later authors of repute. The fact of such a conflicting and unsettled synonymy still pervading the monographs relating to the human structure, should stimulate the well-wisher to the right progress of anatomy to lend an earnest aid to the establishment of a fixed and determinate nomenclature. A little present labour and the example of adoption, where the reasonableness and necessity of the reform are plain and undeniable, will much accelerate the future progress of anatomical science; and I would respectfully appeal to the Professors and Demonstrators of Human Anatomy for an unbiassed consideration of the advantages of the terms proposed in the first column in Table I. It is designed to express the results of a long series of investigations into the special homologies of the bones of the head, in simple and definite terms, capable of every requisite inflection to express the properties of the parts, and applicable to the same bones from the highest to the lowest of the vertebrate series.

Apology for Terms.—The degree and extent of the diversity of my determinations from those of other anatomists are shown in the succeeding columns, headed by their names; and I proceed now to give the reasons which have compelled me, in such instances, to dissent from the high authority of Cuvier, Geoffroy, Meckel, Hallmann and Agassiz: these reasons will exonerate me, I trust, from the reproach of underrating their justly-esteemed opinions, which have been abandoned only where nature seemed clearly to refuse her sanction to them. The instances of such dissent are much fewer than they appear to be at first sight. In most cases, where the names differ, the determinations are the same. For 'basilaire,' which Cuvier exclusively applies to the 'pars basilaris' of the occiput, and which Geoffroy as exclusively applies (in birds) to the 'pars basilaris' of the sphenoid, I have substituted the term 'basioccipital' (*basi-occipitale*, Lat.); a term which, as it is more descriptive of the bone in question (1 figs. 1 to 25), will, perhaps, be the more acceptable to those who prefer a determinate to a variable nomenclature, since Cuvier himself has almost as frequently applied to that bone the term 'occipital inférieur' as the term 'basilaire.' For the descriptive phrase 'occipital latéral,' the term 'exoccipital' (*exoccipitale*, Lat.), proposed by Geoffroy, is preferable for the bones 2,2, figs. 1 to 25; especially since the paroccipital is the most 'lateral' of the elements of the occipital bone, in the definite sense in which the term 'lateral' is used in the precise and excellent anatomical nomenclature of Dr. Barclay. For the numerous synonyms borne by the element 3 of the occipital segment of the skull, the term 'supraoccipital' (*supra-occipitale*, Lat.) seemed to best agree with the truest descriptive phrase of the part, viz. 'occipital supérieur.' The interparietal is no constant cranial element, nor is it a dismemberment of one and the same bone of the skull. It is at best only the largest and most common of the accidentally intercalated 'ossa worniana.' Sometimes, for example, in the *Cebus* monkey, it is a dismemberment of the backwardly-produced frontal bone: more frequently it is the detached upper angle of the supraoccipital. But by this term 'supraoccipital,' I signify the totality of the bone 3 (in figs. 1, 5, 18, 22, 23, 24, 25), confining the term interparietal to its superior and anterior apex when detached, or to the superior and posterior apex of the frontal, when it is in like manner detached and wedged between the parietal bones. The inapplicability of the term 'interparietal' to the whole of the supraoccipital is strongly manifested in those fishes, *e.g.* the carp and tench, in which the supraoccipital is withdrawn from between the parietals to the back part of the skull, leaving those bones to come into contact and unite by the normal sagittal suture on the mesial line of the vertex. Geoffroy's error is of the same kind, and scarcely greater than Cuvier's, where he applies the term 'interparietal' to the whole of the parietal bones in Birds*. The supraoccipital thus defined can never be mistaken for the 'sur-occipital' of Geoffroy, who by this term signifies the elements called 'occipitaux externes' by Cuvier. At the same time the term 'sur-occipital' is too near in sound to 'supraoccipital,' and too significant of the highest part of the occipital segment to be retained for elements, which, like the 'paroccipitals' (fig. 1, 4, 4), are usually inferior in position to the supraoccipital. Geoffroy, moreover, is not consistent in his application of the term 'sur-occipital.' In his memoir on the skull of the crocodile in the 'Annales des Sciences' for 1824, he applies that term to a part of the bone†, the whole of which he calls 'exoccipital' in his later memoir, on the skull of the crocodile, of 1833‡; whilst in the memoir illustrated by the skull of the Sea-perch (*Serranus gigas*) in the 'Annales des Sciences' for 1825, the term 'suroccipital' is applied to the whole of the bones described as 'occipitaux externes' by Cuvier. I trust, therefore, to have shown the necessity for the definite name of 'paroccipital' (*paroccipitale*, Lat.) which is here proposed for the elements, 4, of the occipital segment of the cranium (figs. 1 and 5). The name has reference to the general homology of the bones in question, as 'parapophyses' or transverse processes of the occipital vertebra. And if the purists who are distressed by such harmless hybrids as 'mineralogy,' 'terminology' and 'mam-

Fig. 1.



Disarticulated epencephalic or neur-occipital arch, viewed from behind: Cod (*Morrhua vulgaris*).

* Annales du Muséum, x. p. 363, pl. 27.

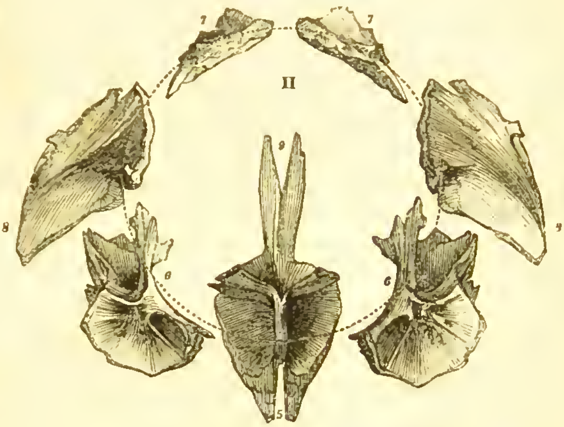
† Pl. 16. fig. 5 z+R. " Plur-occipital formé du sur-occipital et de l'ex-occipital."

‡ Mémoires de l'Acad. Royale des Sciences, t. xii. Atlas, p. 43.

malogy,' should protest against the combination of the Greek prefix to the Latin noun, I can only plead that servility to a particular source of the fluctuating sounds of vocal language is a matter of taste; and that it seems no unreasonable privilege to use such elements as the servants of thought; and, in the interests of science, to combine them, even though they come from different countries, where the required duty is best and most expeditiously performed by such association.

For the same motive that suggested the term basi-occipital, viz. because the anthropotomist has been long accustomed to hear that and the corresponding element of the sphenoid bone described as 'basilar processes,' I propose to substitute the term 'basisphenoid' (*basisphenoideum*, Lat.) for the three different descriptive phrases applied to the part (5, figs. 2, 5, 19, &c.) by Cuvier, for the two additional synonyms of Geoffroy, and for the 'sphenoideum basilare' of Hallmann. 'Alisphenoid' (*alisphenoideum*, Lat., 6, 6, figs. 2. 5, 19, &c.) seemed to retain most of the old anthropotomical term of 'alæ majores,' or wings 'par excellence' of the os sphenoideum; as 'orbitosphenoid' (*orbito-sphenoideum*, 10, 10, figs. 3 and 20) best recalls or expresses the idea conveyed by the descriptive phrase 'alæ orbitales,' or 'ailes orbitaires,' often applied to the homologous bones, regarded as processes of the sphenoid in human anatomy. Here, however, in reference to the alisphenoid, we find the first marked discrepancy in the conclusions of the anatomists who have particularly studied its special homologies. The bone which appears as the 'grande aile du sphénoïde' to Cuvier and Agassiz in fishes, is the 'petrosum' to Hallmann and Wagner; it is also 'rocher' (petrosal) to Cuvier himself in reptiles, and is again 'grande aile du sphénoïde' in birds and mammals. The reasons which have led me to the conclusion that the bones so denominated, as well as the 'ptéreal' and 'prérupeal' of Geoffroy, are homologously one and the same, are so intimately linked with the consideration of the true petrosal and of other elements of the anthropotomist's 'temporal bone,' that I reserve the discussion of these questions until I have completed the apology for the names proposed in the first column of Table I.

Fig. 2.

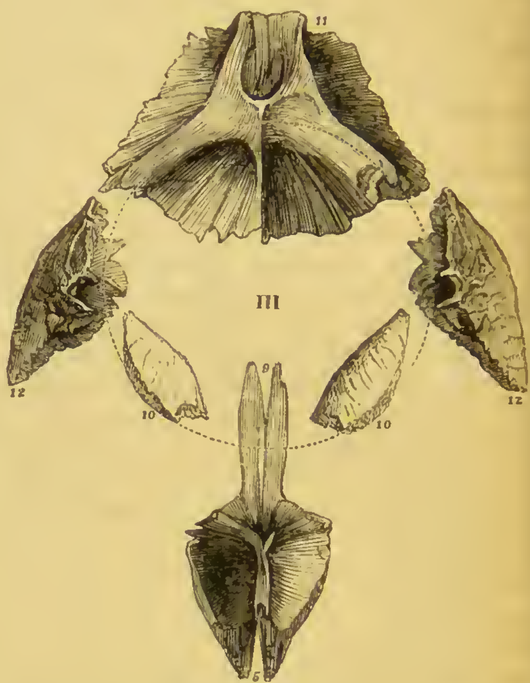


Disarticulated mesencephalic or neuro-parietal arch, viewed from behind: Cod-fish.

The 'parietal' (*parietale*, Lat., 7, 7, figs. 2, 5, 19, &c.) and 'mastoid' (*mastoideum*, Lat., 8, 8, figs. 2, 5, 19, &c.) are amongst the few bones that have had the good fortune to receive, originally, definite names, applicable to them throughout the vertebrate series; although the mastoid, being like the paroccipital, essentially a parapophysis, loses its individuality sooner than do other bones of its segment, and becomes, therefore, a 'processus mastoideus ossis temporis,' in the language of anthropotomy. The homology of the 'parietal' has fortunately been, with a single exception, universally recognised throughout the vertebrate subkingdom; the exception being furnished by the eccentric homologist Geoffroy, who is, as usual, inconsistent with himself, even on this plainest and least mistakeable point.

The term 'presphenoid' (*presphenoideum*, Lat. 9, figs. 3, 5, 20, 24, 25, &c.) is proposed for the 'sphénoïde antérieur,' on the principle of substituting, as the better instrument of thought, a definite name for a descriptive phrase. For the same reason 'postfrontal' (*postfrontale*, Lat., 12, 12, figs. 3, 5, 20, &c.) is substituted for Cuvier's 'frontal postérieur' and its synonyms. The 'frontal' (*frontale*, Lat. 11, figs. 3, 5, 20, &c.) and 'vomer' (*vomer*, Lat., 13, figs. 4, 5, 20, 25), are among the few bones which have had their special homologies recognised unanimously throughout the vertebrate sub-kingdom; in the one case even without departure from the original anthropotomical name, and in the other, with but a single deviation from the established nomenclature. But when Geoffroy was induced to reject the term 'vomer' as being applicable only to the peculiar form of the bone in a small proportion of the vertebrata, he appears not to have considered that the old term, in its wider application, would be used without reference to its primary allusion to the ploughshare, and that becoming, as it has, a purely arbitrary term, it is superior and preferable to any partially descriptive one. 'Rhinosphénal,' it is true, recalls the idea of the vomer forming the continuation in the nasal segment of the skull of the basi- and pre-sphenoidal series of bones in other segments; but 'vomer,' used arbitrarily, summons equally every idea derived to form the complex whole from the general study of the bone throughout the vertebrate series.

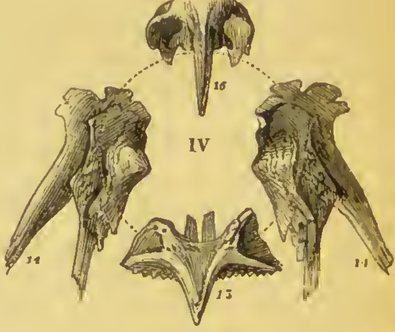
Fig. 3.



Disarticulated prosencephalic or neuro-frontal arch, viewed from behind: Cod-fish.

'Prefrontal' (*prefrontale*, Lat., 14, 14, figs. 4, 5, 21, &c.) claims the same preference over anterior frontal, and its foreign equivalents, as does postfrontal over its synonymous phrases. There is also another reason for proposing the term; viz. because it is applied to bones in the vertebrate series generally, according to conclusions as to their homological relations, which differ from those to which Cuvier and Geoffroy had arrived. The discussion of the discordant denominations at present applied to this important element of the skull will be fully carried out in the sequel. 'Nasal' (*nasale*, 15, figs. 4, 5, 21, &c.) is another of the few instances in which it is possible to retain and generally apply an old and received anthropotomical term. No one, it is presumed, will con-

Fig. 4.



Disarticulated rhinencephalic, or neuro-nasal arch, viewed from behind: Cod-fish.

tend for the perpetual expression or insertion of the understood generic word 'bone' or '*os*' in this case any more than in the parietal, frontal, &c., which, from being originally specific adjectives, have been properly and conveniently converted into definite nouns.

In conformity with this mode of acquiring an improved as well as brief and precise expression of anatomical facts, I have substituted for 'pars petrosa' or 'os petrosum' the substantive term 'petrosal' (Lat. *petrosum*, figs. 5, 25, 16). The necessity for some such designation for an essentially and often physically distinct bone in the vertebrate skull has been felt by both Cuvier and Geoffroy, when they respectively proposed the names 'rocher' and 'rupéal' for the element in question. 'Petrosal' has appeared to me to be the best English equivalent of Cuvier's 'rocher'; as containing the most characteristic vocable of the old anthropotomical descriptive phrase 'pars petrosa ossis temporis,' &c. 'Rupéal' unfortunately has no determinate meaning: it is applied by its author with certain prefixes to several distinct bones, which already had their proper names. 'Sclerotal' (*sclerotale*, Lat., figs. 5, 22, 23, 17) for 'ossicula seu laminæ osseæ membranæ scleroticæ,' is proposed on the same grounds as exoccipital, postfrontal, &c., viz. the substitution of a name for a phrase. The sclerotals have not been usually included amongst the bones of the head, though they have precisely the same claims to that rank as the petrosals, or other bony capsules of the organs of special sense. Retaining the old anthropotomical term 'ethmoid,' I restrict its application to the very irregular and inconstant developments of bone in the cartilage or membrane which is applied to the anterior outlet of the cranium proper, for the support or defence of the cranial part of the organ of smell. The 'ossa turbinata superiora,' and the 'cellulæ æthmoideæ' are parts of the capsule of that sense, extensively developed in the mammalia, to which the term ethmoid may properly apply; but they must always be distinguished from the modified though constant neurapophyses of the nasal vertebra, called 'prefrontals,' with which the above developments of the olfactory capsule usually coalesce in birds and mammals. 'Turbinal' (*turbinale*, Lat., figs. 5, 25, 19), like petrosal, is a substitute for the phrase 'os turbinatum inferius,' and its synonym 'os spongiosum inferius.'

'Palatine' (*palatinum*, Lat., *ib.* 20) is another of the few fortunate instances of the general recognition of the homologous bone throughout the vertebrate kingdom, with the further advantage of a steady retention of a good old name.

'Maxillary' (*maxilla*, Lat., *ib.* 21) is a similar instance; but Geoffroy, as usual, makes himself singular by adding an uncalled-for synonym. If Soemmerring's term 'mandibula' for the lower jaw were universally adopted and constantly understood to signify the totality of that part of the tympano-mandibular arch throughout the vertebrate series, it would be unnecessary to encumber 'maxilla' with the distinctive epithet 'superior,' which, indeed, expresses a character peculiar only to Man and a few mammalia: in the vertebrate series the 'maxilla' is more commonly anterior than superior to the 'mandibula.'

I have adopted the term 'premaxillary' (*premaxillare*, Lat. *ib.* 22), as used by M. de Blainville and some other distinguished continental osteologists, in preference to 'intermaxillary;' because that term has already been applied (by Schneider) to another bone of the skull (the tympanic in birds), of which it is more accurately descriptive, than it is of a bone which is more commonly before than between the maxillary bones. 'Entopterygoid' (*entopterygoideum*, Lat.) claims preference to the phrases 'ptérygoïde interne' of Cuvier and Agassiz, on the same logical grounds as have already been urged in favour of 'exoccipital,' 'prefrontal,' &c. But I have also another reason for proposing a definite term for the bone 23, fig. 5, which I regard as a peculiarly ichthyic development. Cuvier has applied the term 'ptérygoïde interne' to another part of the diverging appendage of the palato-maxillary arch, which part, I concur with Dr. Köstlin in regarding as homologically distinct from the 'entopterygoid' of fishes. For the part in question, viz. the 'os transverse' of Cuvier in the skull of fishes (24, fig. 5), and its homologue in reptiles, which he calls 'ptérygoïdien interne' (24, fig. 22), I retain the term 'pterygoid' (*pterygoideum*, Lat.), meaning pterygoid proper: and to the bone which Cuvier calls 'transverse' in reptiles (24′, fig. 22), I apply the term 'ectopterygoid' (*ectopterygoideum*, Lat.); but this, as the table demonstrates, does not signify Cuvier's 'os transverse' in the skull of fishes. Entopterygoid, pterygoid and ectopterygoid, have, therefore, both the advantages of substantive terms, and of being applied steadily each to a distinct bony element. The 'hérisséal' of Geoffroy, like the 'ptérygoïde interne' of Cuvier, means one thing in a fish and another in a crocodile; Geoffroy has also encumbered the latter bone with a third synonym. 'Malar' (*malare* or *os malæ*, Lat.) is preferable to 'jugal,' because Cuvier applies that name to one bone in a fish, to another in a mammal, and to two essentially distinct though coalesced bones in a bird. Malar is also the name most commonly applied by English anthropotomists to the bone, to the true homologue of which I would restrict its application throughout the vertebrate series.

With regard to the 'squamosal' (*squamosum*, Lat. pars squamosa, &c., figs. 22–25, 27), it may be asked why the term 'temporal' might not have been retained for this bone. I reply, because that term has long been, and is now universally, understood in human anatomy to signify a peculiarly anthropotomical coalesced congeries of bones which includes the 'squamosal' together with the 'petrosal,' the 'tympanic,' the 'mastoid,' and the 'stylohyal.' It seems preferable, therefore, to restrict the signification of the term 'temporal' to the whole (in Man) of which the 'squamosal' is a part. To this part Cuvier has unfortunately applied the term 'temporal' in one class and 'jugal' in another: and he has also transferred the term 'temporal' to a third equally distinct bone in fishes; whilst to increase the confusion, M. Agassiz has shifted the name to a fourth different bone in the skull of fishes. Whatever, therefore, may be the value assigned to the arguments which will be presently set forth, as to the special homologies of the 'pars squamosa ossis temporis,' I have felt compelled to express the conclusion by a definite term, and, in the present instance, have selected that which recalls best the accepted anthropotomical designation of the part, although 'squamosal' must be understood and applied in an arbitrary sense, and not as descriptive of a scale-like form, which, in reference to the bone so called, is rather its exceptional than normal figure in the vertebrate series.

The term 'tympanic' (*tympanicum*, Lat.) appears to have received the most general acceptance as applied to that bone which the early ornithotomists have called 'os quadratum' and 'os intermaxillare,' (fig. 23, 28) and which as a process of the human temporal, sometimes called 'external auditory,' supports the tympanic membrane (fig. 25, 28). 'Caisse' is the French and 'pauke' the German equivalent; but Cuvier more commonly uses the phrase 'os tympanique.' The chief point, in reference to that term, as applied by Cuvier, from which I find myself compelled to dissent from the great and ever-to-be-revered anatomist, relates to the view which he has taken of the large and long pedicle which supports the mandible in fishes, and which, in that class, is subdivided into sometimes two, sometimes three, and commonly into four pieces. I regard this subdivision of the elongated supporting pedicle as explicable chiefly, if not solely, by reference to a final purpose, viz. to combine strength with a certain elastic yielding and power of recovery, in the constant and powerful movements to which it is subject in the transmission of the respiratory currents, and in the prehension and deglutition of the food. Cuvier himself regards in the same light the analogous subdivision of the mandibular or lower half of the arch, and both Conybeare* and Buckland† have well illustrated the final purpose which the subdivision of the lower jaw of the Crocodile into overlapping pieces, subserves. Cuvier has given distinct and convenient names to these several pieces of the mandible, but he views them collectively as answering to the simple mandible of the mammal and the bird. I, in like manner, regard the subdivided pedicle supporting the mandible in fishes as answering to the undivided pedicle supporting the mandible in ophidians, lizards and birds. There is the same necessity or convenience for a distinct name to each distinct part of the tympanic pedicle, or upper part of the tympano-mandibular arch, as for the divisions of the mandible or lower part of that arch. But Cuvier unfortunately persuaded himself that the subdivisions of the tympanic pedicle in fishes represented other bones in higher vertebrates besides the tympanic, and applied to them the names of such bones. I have been compelled, therefore, in dissenting from this view to propose new names for the peculiar ichthyic subdivisions of the tympanic, and in doing so I have been careful to retain the dominant term, and to distinguish the parts by prefixes indicative of their relative position. Time and the judgement of succeeding homologists will determine the accuracy or otherwise of this view; and, should it be ultimately adopted, I feel great confidence that the terms 'epitympanic' (*epitympanicum*, Lat., fig. 5, 28*a*), mesotympanic (*mesotympanicum*, 28*b*), pretympanic (*pretympanicum*, 28*c*) and hypotympanic (*hypotympanicum*, 28*d*), will be preferred to the names proposed by Geoffroy St. Hilaire for the same parts. With regard to the subdivisions of the mandible in cold-blooded vertebrates, I adopt most of those proposed by Cuvier. As, however, 'operculaire' had been applied by the great anatomist to a distinct bone in fishes, it was necessary, in order to avoid its use in a double sense, to substitute a distinct name for the part of the jaw in question, and as it is always applied, like a surgeon's splint or plaster to the inner side of most of the other pieces, that of 'splenial' (*splenium*, Lat., figs. 22, 23, 31) suggested itself to me as the most appropriate name. For an obvious reason I have restored the term 'coronoid' (*coronoideum*, 31′) in place of 'complementary,' for the piece into which the crotaphite muscle is always more or less inserted in the mandible of reptiles. There is no ground for disturbing the appropriate names given by Cuvier to the parts of the diverging appendage of the tympano-mandibular arch in fishes; and the same principle which he has adopted in distinguishing the different opercular bones (fig. 5, 34–37), has guided me in naming the different parts of the bony pedicle which supports them.

I have gladly adopted as many of the well-devised terms which Geoffroy proposed for the elements of the hyoid arch, as his unsteadiness in their application would permit to be retained. They are obviously preferable to the descriptive phrases by which Cuvier designates the homologous parts.

The substantive terms applied to the corresponding divisions of the branchial arches have been modelled on those of the hyoid system; but I have deviated in one instance from the rule which has governed throughout my nomenclature of the bones, in proposing a second name for a modified homologue in the air-breathing animals, of a part of the branchial apparatus in fishes, viz. that part which is retained even in the human hyoid, and which is known in anthropotomy as the 'os laterale linguale,' or 'cornu majus ossis hyoidei;' for this part I have proposed the name 'thyrohyal,' for the reasons assigned in the note (2) to Table I.

The names assigned to the bones of the scapular arch (figs. 5, 22, 23, 24, 25,

* Geol. Trans., vol. v. p. 565. † Bridgewater Treatise, vol. i. p. 176.

23, 50–52) and its appendages (*ib.* 53–58) agree so closely with those which they have always borne as to require no explanation here. The chief surprise of the anthropotomist will be occasioned by their being included amongst the bones of the head. That the upper or pectoral extremity and its supporting arch form actually parts of the integral occipital segment of the skull, will be proved in the memoir on the general homologies of the bones of the head. I may, here, however, in reference to the terms 'ulna' and 'radius,' request the anatomist to compare the skeletons of the perch or cod with that of the porpoise. The pectoral extremity is in the form of a fin, and in both fish and marine mammal it is applied, in a state of rest, prone to the side of the trunk; in this position it will be seen in the *Delphinus*, that the radius is downward, and the ulna with its projecting olecranon upwards. I take this as the guide to the homology of the two bones that support the carpal series of the pectoral fin in fishes. Cuvier, however, gives the name of 'cubital,' perhaps on account of its angular olecranoid prolongation, to the lower bone, and 'radial' to the upper bone: and in these determinations he is followed by M. Agassiz. Both bones coalesce with the supporting arch in the lophius and some other fishes; and since, in the lophius, two of the carpal bones are unusually elongated, Geoffroy mistook these for homologues of the radius and ulna. The condition of the pelvic member or ventral fin is, in fact, here repeated in the pectoral; there being no homologous segment of thigh or leg interposed in any ventrals between the supporting (pelvic) arch and the fin-rays representing the tarso-metatarse and phalanges. The earlier stages in the development of all locomotive extremities are permanently retained or represented in the paired fins of fishes. First the essential part of the member, the hand or foot, appears: then the fore-arm or leg; both much shortened, flattened and expanded, as in all fins and all embryonic rudiments of limbs: finally comes the humeral and femoral segments; but this stage I have not found attained in any fish. It is with considerable doubt that I place, qualified by a note of interrogation, Cuvier's "troisième os qui porte la nagoire pectorale" as the homologue or rudimental representative of a 'humerus.' Normally, I believe this proximal member of the radiated appendage of the scapular arch not to be distinctly eliminated from that arch in the class of fishes. The Siluroids are examples of a similar confluence of the first segment (preoperculum) of the diverging appendage of the tympanic arch with that arch. With regard to the lower, distal or apical element of the scapulo-coracoid arch, always the largest bone of the arch in fishes, Cuvier's idea that it is the 'humerus,' far less accords with the law of the development, the connections, and the essential nature of that bone, than the more prevalent view, that it represents the clavicle: a view entertained by Spix, Meckel, and Agassiz, by Wagner, who calls it 'vordere Schlüsselbein,' and by Geoffroy, who calls it 'furculaire.' I have, however, been induced to regard the lower element of the scapular arch, in fishes (fig. 5, 52), as homologous with that bone, the 'coracoid,' which progressively acquires a more constant and larger development in descending from mammals to fishes, and which is manifestly a more essential part of the arch than the clavicle, since it is more constant in its existence, and always more completely developed in birds and reptiles; and especially since it contributes more or less of the surface of attachment for the radiated appendage, which the clavicle never does. With reference, also, to the Cuvierian determination of the hæmapophysial portion of the occipital inverted arch in fishes, this is unquestionably as essential an element of the arch as is the 'coracoïde' in other vertebrates; and it is the most important part in the piscine class, in no member of which does it present the slightest approach to the character of

Disarticulated bones of the neural arches (N I to IV) and sense-capsules; the hæmal arches (H I to IV) and appendages in diagrammatic outline. Cod (*Morrhua vulgaris*).

a diverging appendage, such as the humerus essentially is, whenever it has an independent existence. By some ichthyotomists, the bone which I call coracoid (52) has received the special name of 'cœnosteon.'

Cuvier's usual judgement and acumen seem to have been in abeyance, when, having determined the rays of the pectoral fin to represent the bones of the hand, and the two bones which support them in fishes to be those of the fore-arm, he concluded that, therefore, the great bone which completed the scapular arch "répondra donc nécessairement à l'humérus."—*Hist. des Poissons*, 4to. i. p. 274. The great anatomist assigns no other reason: but he arch supporting the ventral fin does not necessarily answer to the tibia or the femur, because neither of these segments are interposed between the arch and its appendage—the modified foot. The scapula of many reptiles, especially of the batrachia, is manifestly, he proceeds to state, composed of two bones. But in those reptiles the arch is completed below by a third bone, which neither Cuvier nor any other anatomist has called 'humerus.' Now Cuvier's 'humerale' in fishes precisely answers to that third bone in reptiles which he rightly calls the 'coracoid' in that class.

The coracoid of fishes being thus determined, it necessarily follows that hat inconstant bone, or pair of bones (53) posterior to it on each side, cannot e, as Cuvier, Geoffroy, Meckel and Agassiz have supposed, the representaive of the 'os coracoïdien' of the reptile and bird. It holds, indeed, as they ave said, the same relative position to the bone 52, here called coracoid, hich the coracoid in the lizard and bird holds to the clavicle in those aniials. But is no account to be taken of the remarkably though normally adanced position of the scapulo-coracoid arch in fishes? Granting, as I shall ive evidence to prove in treating of the general homologies of the bones, iat the bone (53) called by Cuvier 'coracoïdien' in fishes appertains to a ertebral segment posterior to the occipital one, yet in the extraordinary backard displacement which the true scapulo-coracoid arch undergoes in the ir-breathing vertebrates, may not the relative position of 53 to that arch ecome reversed, and the part which is behind in fishes become before in irds? I entertain no unmeet confidence in the correctness of my view of the ecial homology of Cuvier's 'os coracoïdien' in fishes with the furculum or clavicle' (fig. 25, 52′) of air-breathing vertebrates: the argument against such view, from its posterior position in fishes, has not, however, the same weight ith me as it appears to have had with Cuvier and his followers: and, leaving iis as one of the undecided points in special homology, with the proposition f the provisional name of 'epicoracoid' (*epicoracoideum*, Lat.) for the piscine one in question, I proceed to consider other unsettled points of special homogy, for the determination of which there are better and surer grounds.

Moot Cases of Special Homology.—The first discrepancy, demanding parcular consideration, which meets the eye in the TABLE I. is that which lates to the determination of no. 6. The German authorities regard what believe to be the homologue of the human 'ala major sphenoidalis' in ie cold-blooded Vertebrata, to be the homologue of the 'pars petrosa ossis mporis.' Cuvier rightly recognises the 'grande aile du sphénoïde' in ammals, birds and fishes, but regards my 'alisphenoid' in reptiles as the rocher' or 'pars petrosa.' Geoffroy concurs with Cuvier and the German iatomists so far as to view my 'alisphenoid' in the Crocodile as a dismemberment of the petrosal, calling it 'prérupéal;' but he recognises, like gassiz and Cuvier, the true alisphenoid in fishes, and with them differs in at respect from the German homologists. It does not appear that the isphenoid has been mistaken for any other bone than the petrosal, and e question to be determined, therefore, is, What are the essential characters respectively of the 'alisphenoid' and the 'petrosal' in the vertebr series?

Those of the *alisphenoid* appear to me to be the following:—1st, its c nection below with the basisphenoid and behind with the petrosal, wher forms the forepart of the 'otocrane' or cavity for the reception of that osse or cartilaginous immediate capsule of the labyrinth or internal organ of he ing: the alisphenoid is also commonly, but not constantly, joined bef with the orbitosphenoid, and above with the parietal: it has other less c stant connections with the squamosal, the exoccipital, the supraoccipital a the basioccipital: 2ndly, with regard to its essential functions, the alisphen protects more or less of the side of the mesencephalon, or (in mammals) the middle lobe of the cerebral hemisphere: it gives exit, by notches or fo mina, to the third, and usually, also, to the second divisions of the trigemi or fifth pair of nerves.

The essential character of the *petrosal* is to envelope immediately t whole of the vascular and nervous tunics of the labyrinth or internal org of hearing, either in a membranous, a cartilaginous or an osseous sta its histological condition being much less constant than that of the alispl noid.

On viewing the alisphenoid on the interior surface of the human sk (fig. 6, 6), it seems to be the least significant and important part of the late

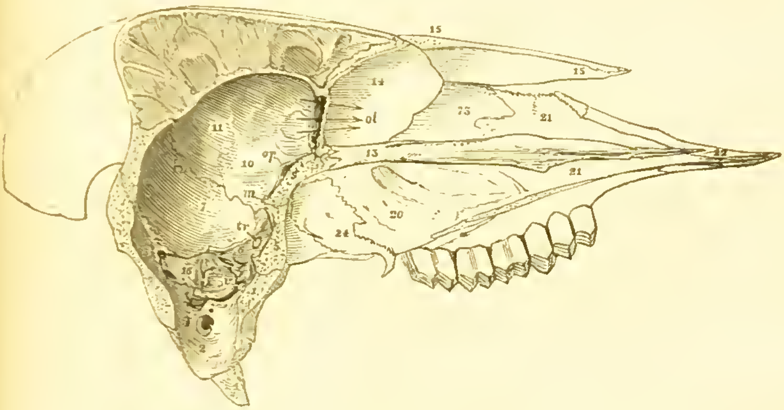
Fig. 6.

Vertical longitudinal section of the human cranium.

walls of the cranial cavity: it forms their smallest portion: it is much su passed in extent by the squamosal (*ib.* 27) and the supra-occipital (*ib.* 3 and still more so by the enormously expanded parietal (7) and frontal (11 Nevertheless we find it connected, anchylosed indeed, below to the basisph noid (5), bounding anteriorly the space into which the petrosal (16) wedged; connected in front with the orbito-sphenoid (10), and usuall articulating by its superior apex with the parietal: I purposely omit th mention of other connections of the alisphenoid in Man which are le constant in the vertebrate series. But it is important to observe, notwitl standing the displacement which the alisphenoid has undergone through th intercalation of the extraordinarily developed squamosal into the lateral wall f the cranium, that it is still perforated by the third (*ib. tr*) and second ivisions of the fifth or trigeminal nerve.

In tracing the alisphenoid downwards through the mammalian series, we can-ot but be impressed with the conviction of its true character and importance s an essential part of the cranium, from its constancy in the formation of its ·alls, and by observing that, whilst the share which the squamosal takes in them rogressively decreases,—until in the sheep, for example, it is quite excluded

Fig. 7.

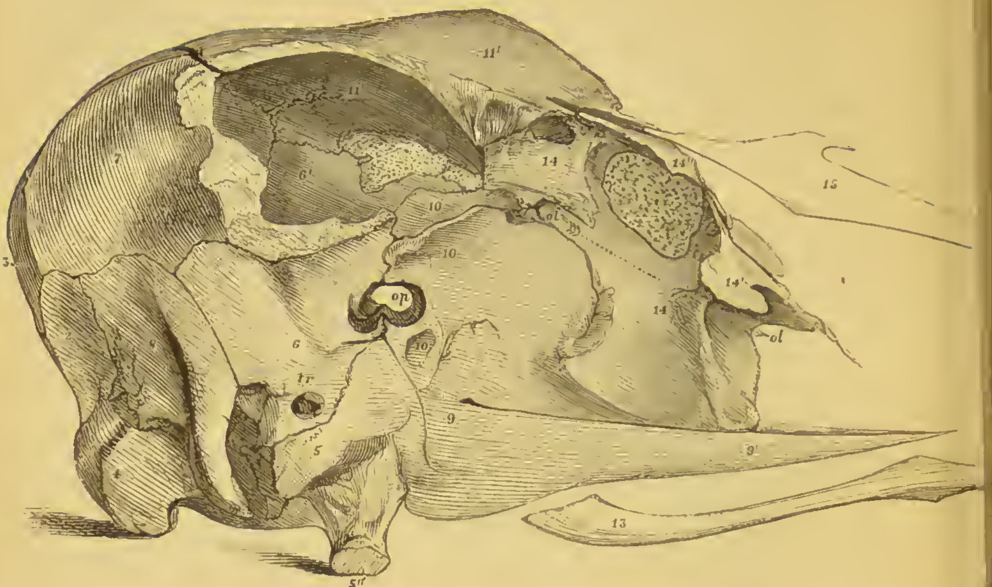


Vertical longitudinal section of the cranium of a sheep (*Ovis Aries*).

om the cranial cavity,—that of the alisphenoid (fig. 7, 6) increases as the vity itself diminishes in size; and, further, that this increase is not accom-.nied with any material change in the relative size of the alisphenoid to the sisphenoid. The share which the alisphenoid takes in forming the ante-›r boundary of the otocrane increases; as does also the extent of its supe-›r connections, especially of that with the parietal (7). It is important, tracing these modifications, to note, also, the change in the relative position the foramen ovale in the mammalian series. In Man the foramen ovale g. 6, *tr*) is close to the hinder border of the alisphenoid; and in some ıadrumanes the third division of the fifth escapes through a notch in the me border. This position of the foramen ovale relates to the alisphenoid ing pushed forward by the intrusion not only of a large ossified petrosal), but of a still larger squamosal (27). In the sheep, however, the fora-n ovale is no longer at the posterior margin; but, the alisphenoid, having trograded by the recession of the squamosal towards its more normal ex-ior position in the vertebrate series, the third division of the trigeminal w perforates its middle part (fig. 7, *tr*). It may be observed that, con-mitantly with this retrogradation of the alisphenoid, the orbito-sphenoid ›. 10) acquires larger proportional dimensions than in Man (fig. 6, 10).

In the bird the alisphenoid (fig. 8, 6) is recognizable by the repetition of e connections which it presented in the sheep; the squamosal being quite cluded from the cranial parietes, and, indeed, never again presenting itself the capacity of a cranial bone in any of the oviparous vertebrates. The sphenoid (fig. 23, 6) is in contact posteriorly with the petrosal (*ib.* 16), ıich soon becomes anchylosed with it, as well as with the exoccipital (2), ıstoid (8), and other bones forming the cavity for the reception of the ear-psule, in all birds. The alisphenoid further manifests its true homology in bird by its other constant character of transmitting the third and also the cond or maxillary division of the trigeminal nerve; which divisions, in the

Fig. 8.

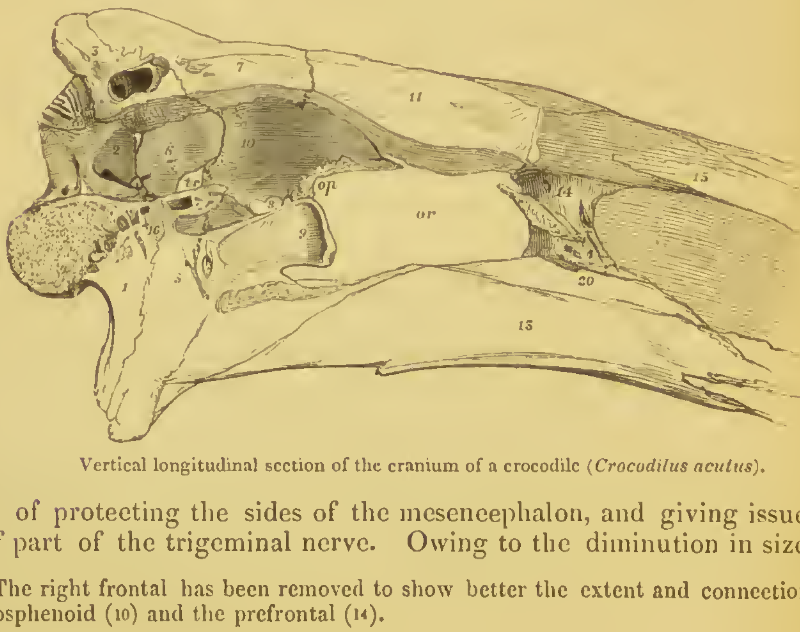


Partly disarticulated cranium of a young ostrich (*Struthio camelus*), natural size.

young ostrich, I found distinctly perforating the middle of its lower bor (fig. 8, 6, *tr*). The alisphenoid is deeply impressed by the chief ganglions of mesencephalon, viz. the optic lobes. The prosencephalon or hemispheres still defended principally by expanded parietals (*ib.* 7) and frontals (*ib.* 11

In the crocodile these spines of cranial vertebræ are much restricted their development, and a larger proportion of the hemispheres is defen by the orbitosphenoid (fig. 9, 10), which here surpasses the alisphenoid (*ib.* in size. This, however, still performs its essential and characteristic fu

Fig. 9.



Vertical longitudinal section of the cranium of a crocodile (*Crocodilus acutus*).

tions of protecting the sides of the mesencephalon, and giving issue to t chief part of the trigeminal nerve. Owing to the diminution in size of t

* The right frontal has been removed to show better the extent and connections of t orbitosphenoid (10) and the prefrontal (14).

etrosal (16), and the retention by a great proportion of this capsule of the coustic labyrinth of its primitive cartilaginous state, it occupies a smaller iterval between the alisphenoid (6) and exoccipital (2). It no longer pro-·udes as a large bony wedge (as in figs. 6 and 7, 16) into the cranial cavity, ut permits the alisphenoid to come into connection with the exoccipital. 'he result of this further retrogradation of the alisphenoid, in regard to the ·lative position of the outlet of the third division of the fifth, is analogous) that which occurs in the sheep. We saw in that mammal, through the ·cession of the squamosal, the foramen ovale advanced from the posterior to ıe middle part of the alisphenoid; in the crocodile, through the further re-.oval from the cranial cavity of the interposed petrosal, the foramen ovale is lvanced to the anterior border of the alisphenoid; which border, in fact, it otches, the nerve escaping by a common foramen or 'trou du conjugaison' etween the alisphenoid and the orbitosphenoid, the hole, however, being ·incipally formed by the alisphenoid (fig. 9, *tr*). This position of the 'fora-en ovale' loses all its value as an argument in favour of the petrosal cha-cter of no. 6, by analogy with the position of the foramen ovale in man · the ape, when we take into consideration the necessary consequences of e successive withdrawal of the squamosal and true petrosal from the inner rface of the cranium in descending to the reptiles. The orbitosphenoid ig. 9, 10), notwithstanding its great relative size, retains all its essential cha-eters: it is perforated or notched for the exit of the optic nerves (*op*) and st division of the fifth pair (*s*); it rests upon the presphenoid (9) below, ıd likewise, through its backward development, partly upon the basisphe-oid, and it articulates with the frontal (11) above, and also through the me backward extension with the parietal (7); it constitutes the anterior order of the lateral bony parietes of the cranium, which are interrupted ' the orbits, and separated by their interposition in saurians and fishes om the rhinencephalic part of the cranial cavity (at 14, fig. 9). The cha-eters, in fact, of the orbitosphenoid are so clearly manifested in the cro-odile, that Cuvier, having been led by the increased share, as compared .th mammals, which the crocodile's alisphenoid (fig. 9, 6) takes in the form-ion of the otocrane, to regard it as the petrosal, and yet perceiving the sential characters of the orbitosphenoid in the bone (*ib.* 10) anterior to it, as driven to the conclusion that that bone represented both orbitosphe-oid ('aile orbitaire du sphénoïde') and alisphenoid (aile temporale du sphé-oïde). The cold-blooded crocodile, however, is not exactly the animal in hich we should expect to find so unusual an instance of obliteration of tures, as that between the alisphenoid and orbitosphenoid*. The actual ıd most characteristic modification of the orbitosphenoid in the crocodile's .ull, is its retrogradation together with the alisphenoid, or rather the main-nance of its normal connection therewith by increased antero-posterior evelopment, whereby it comes into communication above with the parietal) and below with the basisphenoid (5); whilst the alisphenoid, in like anner, gains a connection with the supra-occipital (3) above and the basi-ceipital (1) below; although it still retains its more normal relations with the arietal, and rests in great part on the basisphenoid (5), as the orbitosphe-oid rests in great part upon the pre-sphenoid (9.) The superior connec-

* No one better appreciated the characteristic persistence of the sutures in the crocodile an Cuvier, when his attention was not diverted from it by a favourite hypothesis. "Le ocodile a cela d'avantageux à l'étude de son ostéologie, que ses sutures ne s'effacent point, t moins n'en a-t-il disparu aucune dans nos plus vieilles têtes," is the remark with which commences his article on the determination of the bones of the head of that reptile ssemens Fossiles, 4to. v. pt. ii. p. 69): but at p. 76, a suture is assumed to be effaced, hich is present in most mammals and all cold-blooded vertebrates, where a wider space es not intervene between the alisphenoid and orbitosphenoid.

tions of the orbitosphenoid and alisphenoid are always less constant than their inferior ones. By these latter characters, and still better by their ne outlets and their relations to the primary divisions of the encephalon, they rightly and truly determinable. The German authors who have lowed Cuvier in his views of the special homology of the alisphenoid in tiles, are more consistent than the great French anatomist in regard to alisphenoid of fishes. Dr. Hallmann, accepting Cuvier's characters of the trosal, taken from its internal position and lodgement of the whole or of the labyrinth*, naturally applies them to the alisphenoid in fishes, adds to the grounds for regarding that bone as the 'petrosal,' that it i some fishes perforated by the opercular branch of the great trigeminal nerv But, admitting the homology of the opercular nerve with the facial nerv mammals, yet its wider homology and essential character as a motor divis of the great trigeminal nerve must not be lost sight of: its origin in c. contiguity with the great sensory portions of the trigeminal in fishes acc better with the character of that nerve as the great spinal nerve of the br than it usually presents in higher classes; and it is surely no important parture of the alisphenoid from its normal character, that it should give to both motory and sensory divisions of the great nerve with which it is intimately associated from man down to the fish. Indeed, the progress withdrawal of the bony petrosal from the interior of the skull and the c comitant backward extension or retrogradation of the alisphenoid, ought prepare us to expect that nerves which traverse the petrosal in mamm should perforate the alisphenoid in reptiles and fishes. And so we f in the carp that the glosso-pharyngeal even perforates the posterior bor of the alisphenoid; but its origin close to the acoustic and facial ner in fishes diminishes the force of the argument which might be drawn fr this exceptional perforation in favour of the petrosal character of the a sphenoid. I concur entirely with Cuvier and M. Agassiz in their deter nation of the alisphenoid in fishes; but, if the great share which that bo in reptiles (figs. 9 and 10, 6) contributes to the formation of the otocra if the anterior position of the foramen ovale, and the superior connection the bone with the supra-occipital, are proofs (as Cuvier believed) of its hom logy with the petrosal in the class *Reptilia,* they ought also, as Hallmann a Wagner contend, to establish the same special homology of the bone (fig. 5, in the class *Pisces.* But none of these are essential characters of the petros The petrosal is a *contentum* and not a *paries*, or any part of the parietes of t otocrane or cranial chamber lodging the organ of hearing: it is the outerm tunic, membranous, gristly, or bony, of the labyrinth or essential part of t acoustic organ. Had the above-cited anatomists clearly appreciated t general homology of the petrosal, they could scarcely have failed to dete its special homologies in the vertebrate series. Cuvier was evidently guid to the true determination of the alisphenoid in fishes, less by its own esse tial characters, than by observing in certain fishes, the perch and cod for e ample, a partial ossification of the acoustic capsule, to which, therefore, l assigned the name 'rocher.' And, having thus satisfied himself of the e istence of the homologue of the 'pars petrosa,' &c., he could not but assig to the bone which rested below upon the basisphenoid, which protected lat rally the optic lobes and gave exit to the third division of the trigeminal nerv the name of 'grande aile du sphénoïde.' But all these characters equall coexist in the bone which Cuvier calls 'rocher' (petrosal) in the crocodile an other reptilia. He was not aware, however, that in both gavials and cr codiles a distinct ossicle, the veritable homologue of the intra-cranial pyr

* Ossemens Fossiles, 4to, t. v. pt. i. p. 81.

† Der vergleichende Osteologie des Schläfenbeins, p. 64.

midal-shaped petrosal of mammals and birds, makes its appearance between the alisphenoid, exoccipital and basioccipital, as at 16, fig. 9. Here, however, it is necessary to offer a few observations on the sense in which I use the term 'petrosal' as applied to that ossicle.

The petrosal, properly so called, considered in its totality, as the immediately investing capsule of the labyrinth or internal organ of hearing, is wholly cartilaginous in many fishes and saurians, and in all batrachians, ophidians and chelonians, and is contained in a cavity or orbit (otocrane) which most, or all of the elements of the occipital and parietal vertebræ concur in forming. A part of the ear-capsule remains cartilaginous in the crocodile; but several portions become ossified around the semicircular canals and rudimental cochlea, which ossifications contract slender adhesions to the smooth otocranial surfaces of the supraoccipital, exoccipital and alisphenoid; and to one of these portions (on the principle on which Cuvier applies the term 'rocher' in fishes) the name petrosal might more particularly be given, as it is more distinct and moveable than the other partial ossifications of the capsule, and contributes to form the 'meatus internus' towards the cranial cavity, surrounds nearly the whole of the 'fenestra rotunda', and one-half of the 'fenestra ovalis' towards the tympanic cavity. Looking upon the inner surface of the lateral walls of the cranium (as at fig. 9), one sees at the bottom of the T-shaped suture* uniting the otocranial laminæ of the exoccipital, alisphenoid, and supraoccipital bones, a fourth osseous element (16), presenting a convex extremity towards the cranial cavity, and completing, with the exoccipital, the lower half of the foramen for the nervus vagus. If this little bone be pressed upon with a needle or probe, it yields and moves, being divided by smooth harmoniæ from both the exoccipital (2) and alisphenoid (6).

The protuberance in question, which thus projects into the cranial cavity, is the rounded angle of the border of the inferior plate of the petrosal, which joins the exoccipital. This lower horizontal plate of the petrosal forms the upper wall of the 'fissura lacera posterior,' and the lower wall of the 'fenestra cochleæ': the fore-part of the horizontal plate bends upwards, twisting and expanding into a vertical oval plate, articulated by its anterior surface to a corresponding sutural surface of the alisphenoid. The lower margin of this plate forms the upper boundary of the 'fenestra cochleæ,' and is continued into a thin plate of bone which divides the 'fenestra cochleæ' from the 'fenestra vestibuli' above. This thin plate of the petrosal joins and is usually anchylosed to the exoccipital: it is the only part of the true petrosal noticed by Cuvier, who describes it as a slender filament of bone which separates the two fenestræ†. Seen edgewise, looking into the tympanic cavity, the plate appears like a filament: and this plate forms the sole connection, when any exists, between the petrosal and the exoccipital. I have always found the sutures persistent between the petrosal and the alisphenoid. The upper border of the 'fenestra vestibuli' is formed by a petrosal, or rather otocranial, process of the alisphenoid.

The part (fig. 9, 16) entering into the formation of the lateral walls of the brain-case, and which is here specially indicated by the name of 'petrosal,' seems to have been overlooked: it is, however, relatively to the alisphenoid or exoccipital, as large as is the petrosal (Cuvier's rocher) in the perch: it has a true osseous texture, and is quite distinct from the lenticular mass of calcareous matter in the adjacent cochlear chamber which Cuvier compares to starch ('amidon durci').

* Suture à trois branches, Cuvier, *l. c.* p. 165.

† Du côté de la caisse la paroi est percée de deux fenêtres transversalement oblongues et séparées par un filet mince." *l. c.* p. 82.

Neither the figure of the interior surface of the cranium of the crocodile, which Spix gives as that of the Nilotic species in his great 'Cephalogenesis,' tab. ii. fig. 6; nor the figure given by Geoffroy of the skull of his *Crocodilus suchus* in the 'Annales des Sciences,' tom. iii. pl. 16, fig. 2; nor that of the *Crocodilus biporcatus*, which illustrates the later memoir by the same author in the 'Mémoires de l'Académie Royale des Sciences,' t. xii. (1833), pl. 1, fig. 2.; nor that (if it be an original figure) published by Dr. Hallmann in his 'Comparative Anatomy of the Temporal Bone' (taf. iii. fig. 49), give any indication of this, in the determination of the homology of the alisphenoid and petrosal, most significant and important ossicle. The proof of its normal character will be afforded by comparisons of the description and figure of the part here given with a section of the cranium of any true *Crocodilus*, *Alligator* or *Gavial*. In the latter, the otocranial plates of the alisphenoid, exoccipital and supra-occipital, project considerably into the cranial cavity. Any one of these plates might be called 'petrosal,' for such reasons as have induced Cuvier to apply that name to the alisphenoid in the crocodile and other reptiles*. We find, indeed, that Geoffroy has applied the equivalent term, by turns, to each. But the true idea of the petrosal should include all those gristly and bony parts of the immediately investing capsule of the labyrinth which occupy the otocranial excavations of the exoccipital, supraoccipital and alisphenoid; and as the ossified portions of the true petrosal, in the crocodile, usually contract a bony union with the parietes of the otocrane, all these bony portions of the immediate capsule of the labyrinth might be called 'petrosal processes' of the bones to which they respectively adhere. That portion which unites to the exoccipital is attached by two lamellæ; it forms a great part of the cochlear cavity, the lower half of the posterior semicircular canal and the hinder half of the external or upper semicircular canals: that plate which belongs to the supra-occipital is attached to its otocranial surface by three points, and forms the upper third part of the anterior semicircular canal and the crus of the posterior canal which communicates therewith: that part which adheres to the alisphenoid forms the anterior crus of the anterior (in Man superior) semicircular canal and the anterior beginning of the external canal. The proper and usually distinct bony portion of the petrosal (fig. 9, 16), which articulates with both alisphenoid and exoccipital, forms part of the 'meatus internus,' nearly the whole of the 'fenestra cochleæ,' and half of the 'fenestra vestibuli': it can only be regarded a 'petrosal process' of the exoccipital by virtue of the very limited anchylosis occasionally contracted by the thin plate dividing the two 'fenestræ,' along with the true petrosal process of the exoccipital above described.

If we compare with the inner wall of the crocodile's cranium that of an ophidian, the python for example (fig. 10), we shall find the walls of the 'otocrane' or chamber of the labyrinth to be contributed by the exoccipital, (2) supra-occipital (3) and alisphenoid (6) in nearly equal proportions; the basioccipital (1), also, being ac-

Fig. 10.

Cranium of a python partially bisected. Natural size.

* Ossemens Fossiles, 4to. 1824, v. ii. pp. 81, 180, 258.

cessory to the formation of the floor of the ear-chamber: the three principal bones are united, as in the crocodile, by a triradiate suture. The petrosal, which, like the squamosal, was gradually more and more withdrawn and shut out from the cranial cavity, as we decended from mammals, now entirely disappears from view: and it retains its primitive cartilaginous state in serpents as it does in chelonians, lizards and batrachians. The essential characters of the exoccipital (2) are manifested by its relative position and connections; by its affording exit for the vagal (*v*) and hypoglossal (*hy*) nerves, and by its protecting the sides of the epencephalon. The alisphenoid (6) is not less clearly indicated by its constant and essential characters; it rests below upon the basisphenoid (5), it articulates above with the parietal (7), and behind with the cartilaginous petrosal; but the otocranial plate being, as in the crocodile, unusually extended backwards, unites with the basioccipital (1), exoccipital (2) and supraoccipital (3), in almost equal proportions, and becomes directly perforated by the acoustic nerve (*ac*). Its chief foramen (*tr*), however, is, as usual, that which answers to the foramen ovale in the human alisphenoid, and which gives passage, as in fishes, to the great third division of the fifth, and to the branch which is homologous with the contribution by the fifth to the 'nervus lateralis' in many fishes, and at the same time with the nerve called 'chorda tympani' in anthropotomy.

In the frog I have given an external view of the alisphenoid (6) and the cartilaginous petrosal (16) in their undisturbed connections, in fig. 13, with the surrounding bones. The alisphenoid is here perforated, as in Man, by both a foramen ovale and foramen rotundum (*tr.*): it forms posteriorly the fore-part of the chamber for the cartilaginous petrosal, and usually coalesces with the mastoid (8), which overarches the petrosal: the back wall of the otocrane is contributed, as usual, by the exoccipital (2); the floor by the homologue of the coalesced basisphenoid and basioccipital. Had the outer part of the petrosal (16) been the seat of a partial ossification, a bone would have resulted corresponding precisely with Cuvier's 'rocher' in the cod and perch: but the immediate capsule of the labyrinth retains the same histological condition in the batrachia as it does in the carp and pike, and as in the salamandroid polypterus and lepidosteus: in the latter fish, at most, the only ossified part of the petrosal forms a small bony cup covering the posterior extremity of the outer semicircular canal*.

The attention of the justly celebrated ichthyotomist of Neuchatel appears to have been too exclusively occupied with the persistent embryonic condition of the 'petrosal' in these highly organized fishes, to gain that true and clear idea of the essential nature of the petrosal of which its partial ossification in the perch and cod is indicative. Adopting the opinion of Cuvier, in preference to that of Meckel and Hallmann, touching the special homology of the alisphenoid, M. Agassiz originally diverged into the opposite extreme of repudiating altogether the existence of a petrosal in the class of fishes. Thus, he says, "Il devrait suffire ce me semble de voir l'organe de l'ouïe présenter des modifications graduées dans toute la série des vertèbres, pour se convaincre que le *rocher* n'existe pas du tout chez les poissons, par plus que les osselets de la cavité du tympan. S'il y avait un *rocher* chez les poissons, ce devrait être un os qui entourerait le labyrinthe et les canaux semicirculaires; mais nous avons vu que ces parties de l'oreille interne se trouvent dans la cavité du crâne sans enveloppe osseuse particulière, et protégées seulement par les parois des os qui entourent le rocher, là ou il existe†."

* This condition answers to that in the human embryo of about the fourth month, in which a light porous bony crust begins to be formed upon the cochlea and semicircular canals commencing with the outer and upper ones, the rest of the petrosal being cartilaginous.

† Recherches sur les Poissons Fossiles, tom. v. p. 66.

M. Agassiz is perfectly accurate in his character of the petrosal, according to its relative position, as completely investing the entire labyrinth (of which, by the way, the semicircular canals are an integrant part in all vertebrates and the largest part in fishes); but he takes a narrow view of its histological characters. The sclerotic is not less essentially a sclerotic in the shark, where it is cartilaginous, than it is in the cod, where it is osseous; neither is it less the eye-capsule and homotype of the petrosal in the mammal because it retains the earliest histological condition of the skeleton, viz. that of a fibrous membrane. And, in point of fact, in those fishes where the essential parts of the internal organ of hearing appear to be protected solely by the parietes of the bones, which, in the animals where the petrosal is ossified, or, as M. Agassiz expresses the fact, 'exists,' surround such petrosal, the vascular and nervous parts of the labyrinth are actually in such fishes more immediately enveloped by the petrosal in its membranous or cartilaginous states. What is peculiar to the petrosal in fishes is, that it is never entirely ossified; and, furthermore, that whenever it is partially ossified, the bony part is external and appears on the outside of the skull, instead of the inside as in crocodiles and birds.

In chelonians a larger proportion of the petrosal intervenes between the alisphenoid and exoccipital upon the inner wall of the cranial cavity than in crocodiles; but it is wholly cartilaginous. In birds, on the contrary, the whole petrosal capsule of the organ of hearing soon ossifies and becomes firmly anchylosed to the parts of the exoccipital, mastoid, alisphenoid and basisphenoid that form its primitive chamber or otocrane: owing, however, to the larger relative size of the ossified part of the proper capsule (petrosal proper) which penetrates the cranial cavity, none of the surrounding bones which contribute accessory protection, have received the name of 'rocher,' or *pars petrosa*. It was chiefly through not recognizing or appreciating the general nature or homology of the 'petrosal' that Cuvier failed to perceive its special homology in reptiles. Speaking of the skull of the crocodile, he says that the petrosal, or 'rocher,' is not less recognizable than the 'tympanic' and other so-called dismemberments of the temporal by its internal position, by its lodging a great part of the labyrinth, and by its contributing essentially to the formation of one of the fenestræ (*l. c.* p. 81). But the part in the crocodile which I regard as homologous with Cuvier's 'rocher' in the perch, is more completely internal in position than is Cuvier's so-called 'rocher' in the crocodile: it contributes a greater share to the formation of the 'fenestra vestibuli,' and it forms almost the whole of the 'fenestra cochleæ.' I have never found the alisphenoid (Cuvier's '*rocher*') in the crocodile, lodging a great proportion of the labyrinth*: the otocranial or petrosal process of the alisphenoid lodges a part only of the anterior semicircular canal, and no part at all of the other semicircular canals. The exoccipital is that tributary of the otocrane which lodges the major part of the labyrinth; it contains, for example, parts of two semicircular canals, and the rudimental cochlea: and, when the middle, usually distinct part of the petrosal is joined to it, the exoccipital may be said to form the whole 'fenestra cochleæ' and a greater part of the 'fenestra vestibuli.' We see, then, that the characters by which Cuvier deems his 'rocher' to be so easily recognizable, are more prominent in the exoccipital than in the alisphenoid: and the choice of the latter by Cuvier as the representative of the 'rocher,' seems chiefly to have been influenced by the more obvious and unmistakeable essential (neurapophysial) characters of the 'occipital latéral' (fig. 9, 2), whilst the accessory character which this bone derives from its lodging and becoming confluent with part of the true petrosal, was not allowed

* "Il loge en grande partie le labyrinthe," *l. c.* p. 81.

) prevail, as in the case of the alisphenoid, in the determination of its special omology.

The supraoccipital, by virtue of its internal position and lodgment of part f the labyrinth, has equal claims to the name of 'rocher,' according to the 'uvierian characters of that bone, and Geoffroy St. Hilaire did not make a ss arbitrary choice in singling out this element as 'le seul rupéal*,' than 'uvier did in choosing the alisphenoid, or, as any other anatomist would do ı preferring any other element of a cranial vertebra in the crocodile to epreseut the ossified ear-capsule of the fish or mammal, because portions of ıat ossified capsule are protected by, or have coalesced with, such vertebral ements. Had Cuvier looked beyond the special homology of the bones of ıe head of the crocodile, and permitted himself to appreciate their higher and ıore general relations, he could scarcely have failed to perceive the corre-ondence of his so-called 'rocher' in batrachians, ophidians, chelonians and urians, to the bone which he so well recognizes as 'the great wing of the henoid' in the perch and cod-fish.

The Mastoid.—In the human embryo of the fifth month a centre of ossi-cation is established on the outer surface of the mass of cartilage occu-ying the interspace between the basioccipital (fig. 11, 1) and exoccipital ?) below, the tympanic (28) and squamosal (27) in front, the supraoccipital ı) behind, and the parietal (7) above: this mass of cartilage incloses the ıembranous labyrinth, about which a light osseous crust has begun to be ormed; and, from the centre (8) established near the outer border of the osterior semicircular canal, ossification radiates to complete that part of the ranial parietes, which, in the adult skull, is impressed on its inner surface by ıe great venous channel called 'fossa sigmoidea,' and developes from its uter surface the 'processus mastoi-eus.' The primitive independence f the base of this process, which ˌerkringius so clearly and accurately elineates in his *tab.* xxxv. *fig.* iii. as ıe posterior of his 'tria petrosi ossis istincta ossicula †,' is a fact of much ıore significance than its brief and ransitory manifestation would lead ıe anthropotomist to divine. The oalescence of the primitively distinct ıastoid with the ossifying capsule of ıe labyrinth is very speedy, being sually complete before the fœtus has assed its fifth month, and a com-osite 'petro-mastoid' bone is thus ormed, which, retaining its indivi-uality in monotremes, marsupials, uminants and many rodents, pro-eeds to coalesce with the additional lements of the 'temporal' bone in man, and with other surrounding cranial ones in birds. In the cold-blooded vertebrata, the mastoid retains, with a few xceptions, its primary embryonic distinctness, as an independent element of he skull. In tracing the modifications of this element downwards from man, ve find the external process from which its anthropotomical name originated,

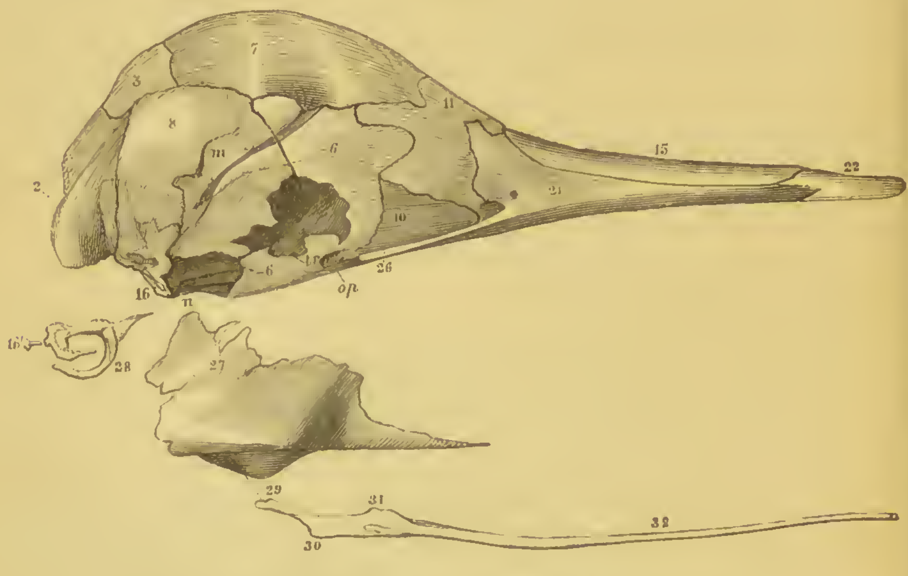
Fig. 11.

Skull of the human embryo; fifth month. Natural size.

* Annales des Sciences Naturelles, tom. iii. 1824, p. 271, pl. 16.
† Spicilegium Anatomicum, 4to. 1670, Osteogenia Fœtuum, p. 269.

inconstant, its functions being transferred in many mammals to another pro-cess, sometimes udder-shaped, sometimes of great length (fig. 24, 4), bu which is developed from the exoccipital, and is represented in the human sku by the 'eminentia aspera,' &c. of Soemmerring (TABLE I. 4), and by the "sca brous ridge extended from the middle of the condyle towards the root of th mastoid process" of Munro (*op. cit.* p. 72); but sometimes also here deve-loped, as a rare anomaly, on one or both sides, into a process like a secon but smaller posterior mastoid*. The more constant and essential character of the mastoid are its contribution to the walls of the acoustic chambe carried to anchylosis with the petrosal in birds and mammals, and its sutura connection in the latter with the exoccipital, parietal, and squamosal (th squamo-mastoid suture becoming obliterated in many species, *e. g.* the hog fig. 24, 8, 27): it is also grooved, notched or perforated by a greater or les proportion of the lateral venous sinus, whether this is continued to the 'fora-men jugulare,' as in man, or sends a large division to escape by the 'meatu temporalis' which forms the large orifice between the mastoid and squamosa above the meatus auditorius in the horse and ruminants, and which directly perforates the mastoid in the echidna (fig. 12, *m*).

Fig. 12.



Partially disarticulated cranium of the *Echidna setosa*. Natural size.

It is important to keep these essential characters steadily in view, and to avoid giving undue importance to the apophysial character of the mastoid, which has led to so common a transference of its name, in the great osteological works of Cuvier and De Blainville, to a quite distinct element (paroccipital) of the cranial walls†. It is necessary, also, to be prepared for that change of the

* The continuators of Cuvier make mention of an example of this kind and propose the name of 'paramastoid' for the process (Leçons d'Anat. Comp. ii. (1837) p. 312). I have observed it in the skull of a New Zealander and in that of an Irishman, preserved in the Museum of Anatomy in Richmond Street, Dublin. Believing it to be the homologue of the 'paroccipital' (4), which is developed independently in chelonia and most fishes, I retain that name for it: it must not be confounded with that angle of the occipital which projects into the 'foramen jugulare' in the human skull, and which has received the name of 'processus jugularis,' in some systems of anthropotomy.

† How essential a correct view of special homology becomes to the appreciation of the

nnections of the mastoid, which results from the gradual withdrawal, in the mmalian class, of the squamosal from the proper cranial walls. With much constancy of relative size in the mastoid, of which the dugong and the walrus er two extremes, we discern upon the whole a progressive increase in de-nding through the mammalian class: in the walrus, for example, the mastoid, petromastoid, forms as large a proportion of the outer lateral walls of the nium as does the squamosal; and, in the sheep, the removal of the squamosal poses the connection of the petromastoid with the alisphenoid,—a return to a ation common in the oviparous vertebrata: it is shown from the inner side the cranium in the sheep, in fig. 7, 16 and 6. The mastoid of the echidna g. 12, 8) presents a most interesting and instructive combination of both the dification of expansion and of that of direct union with the alisphenoid (6), ich is here effected by the mastoid plate independently of the petrosal (16). fig. 12 these characters are well exposed by the removal of the squamosal and tympanic 28, which retain their primitive independence throughout in the echidna. If now we compare the bone 8 and 16 with the carti-ginous and osseous mass 8 and 16 in the skull of the human embryo (fig. 11), d allow for the change produced in the position of the alisphenoid (6) by gradual withdrawal of the squamosal (27), traceable in the intervening ms of mammalia, the special homology of the petromastoids at the two ex-mes of the mammalian class will be obvious and unmistakeable. The bone nd 16 in the echidna, fig. 12, is connected below and behind with the basi-cipital and exoccipital (2), behind and above with the supraoccipital (3) and rietal (7), in front with the tympanic, the squamosal, and also, as a conse-ence of the modified position of the latter and of its own increased deve-ment, with the alisphenoid (6). All the connections, save that with the sphenoid, are identical with those of 8 and 16 in the human embryo; and supervening alisphenoidal connection in the echidna affords an additional ht to the determination of the bone in the lower vertebrata, since it is a nsequence of the progressive advance to a lower (oviparous) type, in the scent through the mammalian scale. In regard to the essential functions the petromastoid, we find the petrosal portion inclosing the membranous yrinth, and the mastoidal portion giving exit to the blood from the great eral venous sinus and supporting the tympanic*. It will be unnecessary dwell further on the broad and obvious characters by which the homology the bone 8 and 16 in the echidna is established with the equally independent tromastoid in the sheep and walrus, and with the petromastoid portion of human 'temporal bone.'

The continuators of the 'Leçons d'Anatomie Comparée,' influenced by the ge proportional size of the petromastoid in the echidna and the share ich it consequently takes in the formation of the cranial parietes, supposed to be the squamosal:—"le véritable temporal, qui n'aurait pour toute ophyse zygomatique qu'un très petit tubercule près de la facette glénoïde,"

her law of general homology may be learnt from the application by Cuvier of his idea of mammalian mastoid to the refutation of the vertebral theory of the skull. "On a aussi uvé quelque rapport entre l'apophyse mastoïde qui, dans la plupart des animaux, appar-nt à l'occipital, et l'apophyse transverse de l'atlas et des autres vertèbres; sur quoi il faut marquer que ces rapports sont moindres dans l'homme à certains égards que dans les qua-pèdes, puisque l'atlas n'y a ordinairement qu'une echancrure pour le passage de l'artère, que l'apophyse mastoïde y appartient entière au rocher."—Resumé sur le question—'Le ne est-il une vertèbre ou un composé de trois ou quatre vertèbres?' Leçons d'Anatomie mparée, t. ii. (1837) p. 711.

* In the article 'Monotremata,' Cyclopædia of Anatomy and Physiology, 1841, I described petromastoid as the petrous bone, misled by the absence of the external character of the cess.

op. cit. t. ii. (1837) p. 377. This tubercle is the rudiment of the masto process, which is so largely developed in birds, and which, in the echidn overhangs the tympanic cavity. There is no glenoid articular surface up the bone 8 and 16. We find, on the other hand, the squamosal under its prop mammalian form and connections, with a long and slender zygomatic proces and performing the function, peculiar to the class Mammalia, of supporti the mandible by the true glenoid articular surface in the echidna (fig. 12, 27)

Dr. Köstlin, whose painstaking and minutely accurate description of t osteology of the vertebrate skull renders his conclusions as to their hom logies worthy of respectful consideration, concurs with me in regard to t squamosal (27) of the monotremes, but regards the bone 8–16 in t echidna as a dismemberment of the alisphenoid. In no mammal, howeve do we find the alisphenoid concerned in immediately protecting the semici cular canals—this is the function of the petrosal: in neither mammal n bird does the alisphenoid extend its connections so far back as to the bas ex- and supra-occipitals. In the echidna, as in every other mammal and bir the alisphenoid (6) exists, exclusively exercising its essential function of tran mitting the third division of the fifth pair by the large vacuity (*tr*) and wit its normal connections modified only, as in the sheep and some other inferi mammalia, through the recession of the squamosal, by joining the mastoi in addition to those which it unites with in man. I confess that I can perceiv no other gain to anatomy by Dr. Köstlin's new determination of 8 and 16 i the echidna as 'hintere Abtheilung des Schläfenflügels' or 'hintern Schlä fenflügel*' (posterior alisphenoid), than an additional phrase to the synonym of the mastoid.

The discussion of the homologies of this bone under its modifications i the mammalia, and especially in the monotremata, will not be deemed super fluous or too detailed, when it is remembered how valuable a key the crani organization of the implacental monotremes with their bird-like heads become to the comprehension of the modifications of the cranial structure in bird themselves. If we pass from the comparison of the echidna's skull, as re presented in fig. 12, to that of the ostrich (fig. 8), we shall find there a bon (8) articulated in front to the alisphenoid (6), behind to the exoccipital (2) below to the basi-occipital and basi-sphenoid, above to the parietal 7, an coalescing by its inner surface with the petrosal. The sole modification o note in regard to connective characters, as compared with the mammalia petromastoid, is the loss of the connection with the squamosal, for which w have been progressively prepared by the conditions of that bone in rodents, ru minants and monotremes. In the bird this least constant element of the crania walls (fig. 21, 27) has undergone a further degradation, is now dismissed en tirely from any share in the formation of even the outer surface of the crania parietes, and is reduced to its mere zygomatic form and function, servin exclusively to connect the jugal (fig. 21, 26) with the tympanic (28); whic function it performs in the echidna and in man, besides other superadde offices arising out of its peculiarly mammalian expansion into a scale-lik lamina, or as compensatory of the reduction of the tympanic bone. Dr Hallmann, however, in his elaborate monograph on the temporal bone, con siders the bone 8 (fig. 8) to be the squamous or zygomatic element, and cites the following characters of the bone, in the young cassowary †, as establishing its homology with the squamosal:—"its junction above with the parietal, in front with the alisphenoid and post-frontal and behind with the occipital; also its formation of the upper border of the meatus auditorius externus, and its

* *Op. cit.* pp. 29, 126.

† Die vergleichende Osteologie des Schläfenbeins, p. 8. pl. 1. fig. 5.

ntribution of the articular surface for the tympanic bone," which surface regards as homologous with the glenoid cavity of the squamosal for the ver jaw in mammals.

Cuvier, whose homology of no. 8 he thus adopts, describes it in the bird being on the outer side of the parietal, advancing also to beneath the ntals, occupying the region of the temporal fossa and giving origin to the nporal muscle, and as forming the superior border of the tympanic cavity. The temporal fossa," adds Cuvier, "is in great part excavated in the temral bone, and is bounded behind by a special process which might be reded as the analogue of the zygomatic did it not remain far removed from jugal bone *." The annotators add, "that there are some species of bird which, nevertheless, such zygomatic process does approach very close to jugal †."

First, then, with regard to the character which appears to have most ghed with Cuvier, from his twice citing it in the above brief definition no. 8,—the marks of the origin of the temporal muscle. To conclude that bone impressed by the so-called 'temporal fossa' in the skull of the bird, herefore the temporal bone, because such fossa impresses a bone called nporal' in the mammal, is an example of that fallacy which logicians call uing in a circle. The two propositions by no means reciprocally prove h other. Suppose, for example, that the bone no. 8 in the bird had been ermined, by way of ascensive comparison from the fish (fig. 5) and croile (fig. 16), to be the homologue of the bone no. 8 in those animals, which will assume to have been rightly called 'mastoid' by Cuvier, and that he arrived at the determination of no. 8 in the bird by this surer method, n by the descent from placental mammals; and supposing that, having thus ognized no. 8 as the mastoid, the fossa and muscle with which it is imssed in the bird had been called 'mastoidal' instead of 'temporal'; then, ending to the mammalian cranium, Cuvier might with equal reason have l that the bone 27, figs. 11 and 22, was the 'mastoid,' because it occupied the on of the mastoidal fossa and gave origin to the mastoidal muscle. The ins of muscles are not, however, sufficiently constant to be included amongst characters of connection or function determinative of special homologies. transference of the 'sterno-mastoideus' from the true mastoid process an, carnivores and rodents) to the angle of the mandible (horse), and to n this part and the second cervical vertebra (ruminants), shows that the chments of a muscle must be determined after the recognition of the bone, not the homology of the bone by muscular attachments. With the very in question the uncertainty of the character is illustrated: in the skull he ostrich, for example (fig. 8), the temporal fossa is chiefly formed by the joined portions of the parietal (7) and alisphenoid (6), which intervene been the mastoid (8) and the postfrontal, the mastoid forming not more of posterior part of the fossa than the postfrontal does of the anterior part. Hallmann probably appreciated the unsoundness of the argument from muscular impression, since he does not cite it; he repeats, however, the racter adduced by Cuvier, from the relation of no. 8 to the tympanic ty, or as Hallmann expresses it, the meatus auditorius (äussern Gehör ung), the value of which therefore I next proceed to consider.

n the skull of the ostrich, with the tympanic bone and ear-drum in place, upper border of the meatus, as defined by the periphery of the membrana pani, is formed, not by no. 8, but by the tympanic anteriorly, and by the occipital process (4) posteriorly. When the tympanic bone and memne are removed, then the descending process of no. 8 overarches the

* Leçons d'Anat. Comp. ii. (1837), p. 580. † *Ib.* p. 581.

upper and forepart of the tympanic cavity so exposed. So much for facts of the argument*.

We may next ask, Is the formation of the upper boundary of the mea externus an essential character of the squamosal in mammals; or is it rather a secondary consequence of the expansion and application of that b to the side of the cranium in this particular class? If we were desirou obtaining a homological character by comparison of the contour of meatus externus or the tympanic cavity in mammals and birds, ought not rather to select the lowest and most ornithoid of mammals, as best culated to throw light upon the real nature of the modifications of this p of the skull in the respective classes? In the echidna, then, we find t the squamosal does not form the whole of the superior border of the shal tympanic cavity, but that the mastoid forms the posterior half of that bor and sends a short obtuse process downwards (at 16, fig. 12), which overha the cavity and gives attachment to the tympanic (28). Behind the mast is the exoccipital. Now in birds the antero-posterior extent of the crani between the exoccipital and postfrontal bones is much shortened as compa with mammals, and this modification I interpret as the result, in a great gree, of the entire removal of the squamosal from the cranial parietes. the homology of no. 4 as a part of the exoccipital there has been no questi although its development, and the share it takes in the lateral parietes of head, is increased, as compared with most mammals, rather than diminish The exoccipital constantly unites anteriorly with the mastoid in mamm from man down to the echidna; but the extension of the squamosal ba wards to articulate with the exoccipital is far from being a constant charac in mammals. We ought on that ground therefore to conclude that the bon which articulates with the fore-part of the exoccipital in the bird, is 'mastoid,' rather than that it is the 'squamosal.' It overhangs the tympa cavity by a longer or shorter process; but being more advanced in positi partly by the development of the exoccipital behind, and the non-interposit of a squamosal between it and the alisphenoid in front, it overarches middle of the upper instead of the posterior part of the upper border of tympanic cavity in the bird; but it is still in great part posterior to the ty panic pedicle, a relative position which is foreign to the squamosal. T process of no. 8 resembles the mastoid process in mammalia, inasmuch it terminates freely in most birds; and in those, the parrot for example (pl fig. 1, 8), in which it joins another process to form a zygoma or bridge o the temporal fossa, that process answers to the postfrontal, the very bo which the mastoid similarly joins in the crocodile, and does not answer to t malar bone, which the squamosal joins in both mammals and crocodiles.

The mastoid always coalesces with the petrosal, rarely with the squ mosal, in the mammalia; such coalescence is therefore a more constant ch racter of the mastoid than of the squamosal, and the argument becom cumulative in favour of the mastoid or petromastoid character of no. 8 in t bird. When we remove the squamosal in the sheep we bring away the ma dible which articulates with it, but we leave the distinct and independent ty panic closely articulated to the petromastoid. Precisely the same thi happens in the rodentia, in the marsupialia, and especially in the echid in which the tympanic has the slightest connection with the squamosal. T articulation of the tympanic therefore with the petromastoid is a more co stant character than its articulation with the squamosal; therefore the ar culation of the unquestioned tympanic bone in birds with the bone no. 8 is

* The same formation of the upper boundary of the meatus externus is shown by Geoff in the young fowl.—Annales du Muséum, x. pl. 27. fig. 2. V. Q.

onger proof of no. 8 being the petromastoid than of its being the squamosal: 1 for the same reasons that the articulation of no. 8 with the exoccipital, and coalescence with the petrosal, are more essential characters of the petro-stoid than they are of the squamosal, so I regard the articular surface nished by no. 8 to the tympanic bone to be homologous with the articular face of the petromastoid for the tympanic in the ruminants, rodents l other mammals, and am compelled to dissent from Dr. Hallmann's idea its answering to the articular surface furnished by the squamosal to the ndible in mammals. In the ostrich a part of the articular cavity for the npanic is excavated in the exoccipital, and would afford as good an argu-nt to prove that bone to be the squamosal as the one which Dr. Hallmann deduced from the same character in favour of the petromastoid in the l being the squamosal. Dr. Hallmann cites the junction of no. 8 (his *t*, i. fig. 5, *op. cit.*) with the postfrontal in a young cassowary as evidence ts squamous character. I have not met with this union in the young ich nor in the young emeu, in which latter bird there is a distinct post-ntal: the anterior inferior angle of the parietal descends and meets the phenoid in both these *Struthionidæ*, at the part where the post-frontal is ·ked (at f'') in Dr. Hallmann's figure above cited. The extremity of the ·toid process does, however, arch over the temporal fossa to join the post-ntal process in certain birds, as above mentioned; but this junction, when ascend in our pursuit of the homologies of the elements of the composite poral bone of mammals, as it is safest to do, from fishes to reptiles, from these to birds, forms a repetition of a very characteristic feature he mastoid in the cold-blooded classes, and one that is quite intelligible ·n we rise to the appreciation of the higher relations of both mastoid and ·-frontal as parapophyses of their respective vertebræ.

n every mammal the squamosal is applied to the cranial parietes, and at-ned by a peculiar suture called squamous; the outer surface of the bone eeding the inner surface. In no bird is the mastoid so united to the sur-nding bones, but joins them by harmoniæ vertical to the surface, as the er true cranial bones are joined before they coalesce; and the outer very e, if at all, surpasses the inner surface, to which the petrosal is confluent. : petromastoid of the mammal resembles that of the bird in this respect.

'here is no difficulty in the ascensive survey in appreciating the special nology of no. 8 in the bird (fig. 23) with no. 8 in the crocodile (fig. 22) in the fish (fig. 5); and Dr. Hallmann, retaining a firmer and more sistent view of their common characters than Cuvier, enunciates clearly homology: but having persuaded himself that the 'mastoid' of the bird its 'squamosal,' he concludes that the bone which Cuvier had called mas-. in the crocodile and fish must also be their squamosal. I believe Cuvier ave rightly determined the bone (no. 8) in the cold-blooded classes to be mastoid; but he is not consistent with himself when he adopts a different clusion with regard to no. 8 in the bird. The greater development of bird's brain, as compared with the crocodile's, requires a greater expan-ı of the cranial part of the mastoid, just as the still greater development he brain in mammals calls forth a peculiar expansion and application of cranial end of the squamosal, involving a transference of the mandibular t to that expanded end.

'uvier, in descending from mammals to the consideration of the homolo-· of no. 8 in the bird, passed too abruptly to the comparison, lacking the ructive link furnished by the monotremes. It might have sufficed for present report to have demonstrated the homology of no. 8 in the bird, ·nsively, with Cuvier's well-determined mastoids in fishes and reptiles;

but since both Cuvier and Dr. Hallmann have elucidated their views o homology by characters drawn from the mammalian class, I have endeavou and I trust satisfactorily, to meet their objections and to determine the homology of the bone by other arguments drawn from modifications of petromastoid in the same class.

Pursuing therefore the comparison descensively, I proceed in the next p to consider the characters of the mastoid in the crocodile (figs. 19 and 22 Cuvier premises his determination of the bone in that reptile by citing following as its characters in the mammalia :—" La partie mastoïdienne recouvre le rocher en arrière de l'écailleuse et de la caisse, mais qui se so de si bonne heure à ce rocher que l'on paroient à peine à la reconn comme distincte dans les plus jeunes fétus où elle est quelquefois doubl The squamosal he defines as a bone " qui devient de plus en plus étran au crâne à mesure qu'on descend dans l'échelle des quadrupèdes, en s que dans les ruminans elle est plutôt collée dessus qu'elle n'entre dan composition de ses parois †." If we pause to apply these characters to the termination of nos. 8 and 27 respectively in the bird, before proceedin the crocodile, we shall see how far they sustain the conclusions I have rived at, in opposition to the views of Cuvier and his followers, in refere to the true homologue of the mammalian squamosal in birds. With reg to the mastoid in the crocodile, Cuvier says, " Le mastoïdien des crococ proprement dits et des gavials a cela de particulier, qu'il s'avance latér ment jusqu'à s'unir au frontal postérieur, et à entourer avec lui et le p étal le trou de la face supérieure du crâne qui communique avec la f temporale ; dans quelques caïmans il s'unit même à ces trois os pour cou entièrement cette fosse en dessus, et dans les tortues de mer, non-seulem ils font la même chose, le temporale et le jugal venant aussi à s'unir au n toïdien et au frontal postérieure, ils couvrent la fosse temporale, même dehors." ‡

Doubtless the German anatomists who dissent from Cuvier's determina of the bone 8 in the crocodile (fig. 22) have been influenced in some deg by the little conformity between the character above assigned to the mast in that reptile and the character Cuvier had previously assigned to the m toid in mammalia. The confluence of the mastoid with the petrosal, example, is a modification peculiar to the warm-blooded vertebrates, wh the relative position of the mastoid, above and external to the petrosal, ab and behind the tympanic, and behind the squamosal, when this bone is p sent, is a constant character in all vertebrates; to which must be added, t in most mammals and all other vertebrates the mastoid affords an articu surface for the tympanic bone, and developes an outstanding (masto process for the attachment of strong muscles moving the head upon the tru With regard to the relative position of the mastoid process to the cra walls, its origin ascends as the expansion and elevation of the parietal di nishes with the decreasing size of the cerebrum : in mammals, the proce when present, extends from the lower border of the postero-lateral wall the cranium : in birds it projects from near the middle of that wall, a nearer the upper surface in the flat-headed *Dinornis* : in the crocodile it l ascended to a level with the upper surface of the cranium, and forms t posterior angle of that surface. The paroccipital presents a similar progr sive ascent, but later in the series traced descensively ; it does not gain t level of the mastoid until we arrive at the class of fishes.

* *Op. cit.* t. v. pt. ii. p. 81.

† *Ib.* p. 81. Oken notices the completion of the cranial cavity, independently of squamosal, in the sheep ; in his " Programm", &c. 4to. 1807, p. 5.

‡ *Ib.* p. 84.

The mastoid, thus determined in the crocodile, is recognized with ease d certainty in chelonia, lacertia and ophidia. It is a distinct bone in all se reptiles, and preserves with singular constancy its normal relative poion anterior to the exoccipital, superior to and supporting the tympanic, d anterior to the squamosal when this is present. In lizards the mastoid much reduced in size: in serpents it attains a considerable length. In the thon and most serpents it forms no part of the proper wall of the cranium, t overlaps the contiguous parts of the parietal, alisphenoid, supra-occipital, l exoccipital, projecting backwards beyond the latter. It is large in the pentiform batrachia, but presents in *Cæcilia* (Cuvier, Règne Animal, 1817, 6. figs. 1 & 2, *g*) its normal connections with the occipital (*f*), parietal , tympanic (*h*), and also with the post-frontal, which has coalesced or is inate with the frontal (at *d*, l. c.). Cuvier does not admit of this conflue in the cæcilia; and although he assigns the character 'point des fronx postérieures' to the typical batrachia*, gives the name 'posterior frontal' h a note of doubt, indeed, to *g*, and assigns to the bone *h*, which suspends mandible, the name of "mastoïdiens et caisses réunis†." There is no ual necessity for assuming so rare a confluence to characterize the cæcilia. e mastoid exists with all its normal connections, and beautifully manifests its independence and large size the affinity of the cæcilia to the true iidia. In the typical batrachia, where the cranium is remarkably chaterized by instances of confluence which seem borrowed from the warmoded classes, the mastoid sometimes loses its independence, and appears in exogenous process from the external and posterior part of the parietal, iining however its normal office of suspending the tympanic: but in a skull the *Rana boans* now before me, the suture between the mastoid (fig. 13, 8) l parietal (7) is not obliterated, and it further articulates with the exoccid (3) behind and the alisphenoid (6) in front. Cuvier, in his description of tympanic of the *Rana esculenta*‡, says, that its upper branch articulates h the 'rocher.' In *Rana boans* that branch articulates exclusively with truncated extremity of the broad outstanding mastoid, which mastoid rhangs, as in all fishes, the petrosal, which is chiefly cartilaginous in the *na boans* (*ib.* 16). In *Rana esculenta* the mastoid (Dugés, Recherches les Batrachiens, fig. 1, 12) appears to have coalesced with the alisphenoid figs. 2, 6 & 7, 12); and the compound bone has received the name of cher' from Cuvier and that of 'rupéo-ptéreal' from Dugés. The fora- a ovale however marks the alisphenoidal part (a distinct bone in my *Rana ns*), and the suspension of the tympanic marks the mastoid, which, with other connections, overhangs also in *Rana viridis* that mass of cartilage§ ich immediately invests the membranous labyrinth and forms the 'fenestra ilis' against which the plate of the columelliform stapes is applied.

Prof. J. Muller has well recognized the homologue of this sense capsule in *Cæcilia hypocyanea*, in which he describes it as "petrosum cum operculo estræ ovalis||." It is situated further back than in *Rana*, and appears poste- to the tympanic (*i*) and the large suspending mastoid (*h*), to which Muller es the name of 'temporale.' In the singularly modified cranium of the *thlops* the mastoid articulates above with the parietal and supraoccipital, iind with the exoccipital, coalesces in front with the alisphenoid, as in ie batrachia, and affords the usual articulation below to the tympanic.

Ossem. Fossiles, v. pt. i. p. 386. † Règne Animal, ed. 1817, t. iv. p. 102.

Ossem. Fossiles v. pt. ii. p. 390.

The precocious development of this capsule in the larva of the frog is well shown by chert, 'Entwickelungsgeschichte des Kopfes,' 4to, pl. i. figs. 13—15, *x*: it resembles in the myxinoids and lampreys.

Beiträge zur Anatomie der Amphibien; Tiedemann's Zeitschrift für Physiologie, iv. 1831, p. 218, pl. 18. fig. v. *k*.

How necessary it is to retain a elcar and eonsistent appreciation of these dences of the homology of the mastoid is shown by the second synonym, petrosum,' whieh it has received from the justly-celebrated author of instructive memoir (pl. 20. figg. 10, 12, 13, 14, *p*). The actual capsul the membranous labyrinth is eovered by the mastoid and exoeeipital, remains wholly eartilaginous, as in other ophidia ; and as it likewise do *Rhinophis*, where its name 'petrosum' is in like manner transferred by I Muller to the coaleseed mastoid and alisphenoid. In *Cheirotes* the eo of confluence proeeeds to obliterate not only the suture between the mas and alisphenoid, but that between the mastoid and parietal; as also of th between the frontal, parietal and supra-oeeipital; the whole eranium senting almost the extent of coalescenee whieh charaeterizes the hot-bloo bird. Only the immediate covering of the membranous labyrinth rem cartilaginous.

The sides of the superior surfaec of the eranium of bony fishes usu extend outwards as a strong irregular ridge, from which three processes n partieularly projeet, which are supported by three distinet bones, sutur united, and eaeh impressed with an artieular glenoid cavity. And her eannot avoid remarking how beautifully the prineiple of vegetative re tition* is exemplified in the lowest class of the Vertebrata, where con quently the relations of serial homology of the parapophyses in question unmistakeable. The posterior process or bone which sustains (in part) seapular arch is the paroccipital (fig. 5, 4); the anterior one, which susta in part the tympano-mandibular arch, is the post-frontal (*ib.* 12); and intermediate and usually most prominent bone (*ib.* 8), which sustains in p the epitympanie (28*a*), and through that the hyoid arch, is the homologue the bone whose essential eharacters have been discussed under the name 'mastoid.' The paroccipital having now risen to a level with the masto this forms the second strong transverse process at eaeh side of the craniu The process is developed from the outer margin of the mastoid; the in side of the bone is expanded, and enters slightly into the formation of walls of the cranial or rather the otocranial cavity, its inner, usually cart ginous surfaee lodging the fibro-eartilaginous continuation of the petro whieh immediately covers the external semicircular canal. It is wedged i the interspace of the ex- and par-occipitals, the petrosal, the alisphenoid, parietal and post-frontal bones. The projecting process lodges above ehief mucous eanal of the head, and below affords attachment to the e tympanic or upper piece of the bony pedicle from whieh the mandibu hyoid, and opereular bones are suspended : its extremity gives attachment the strong tendon of the dorso-lateral muscles of the trunk.

It might have been supposed that this eontribution to the walls of t eranial cavity, this articulation to the oceipital and tympanie bones, all whieh are eonstant characters of the mastoid in mammals, and but oecasio ones in the squamosal—not to speak of the apophysial form and funetions the bone in question in the skull of fishes—would have made the balanee eline to the choice of the 'mastoid' rather than of the 'squamosal' eleme of the human temporal in the judgement of every unbiassed investigator its homologies. The German anatomists, however, in falling with Cuv into the mistake respecting the homology of the 'mastoid' (no. 8) in bir with the squamosal in mammals, adhere more consistently to their error a eontinue to apply the name 'squamosal' or its equivalents to the homologo bone in reptiles (fig. 22, 8) and fishes (fig. 5, 8).

* This principle or law is explained in the first volume of my Hunterian Lectures 'On Invertebrata,' 8vo. 1843, in whieh classes of animals it is most strikingly and fully exe plified.

The high repute which M. Agassiz has so justly earned in ichthyotomy ders the accession of his name in support of Drs. Hallmann, Reichert, l Köstlin's determination of the bone in question, one to which those able nologists and their followers will naturally attach great weight, and which eed has caused me to pause and retrace more than once, and with the nost pains and care, every step in the series of comparisons which have illy brought conviction of the accuracy of the Cuvierian determination of s in fishes.

[am not aware that any anatomist has replied to the objections to the vierian view propounded by M. Agassiz. Drs. Hallmann and Köstlin, o have published the most elaborate monographs on the temporal and er bones of the skull since the time of Cuvier, concur entirely with the rned Swiss naturalist. Dr. Reichert, in giving the name of 'squama temalis' to no. 8, and that of 'processus temporalis posterior' to its process, nsfers the name 'processus mastoideus' to the paroccipital (no. 4, fig. 5)*. becomes then necessary to consider the arguments of M. Agassiz in favour the homology of no. 8. in fishes with the squamosal no. 27 in mammals. the valuable monograph on the osteology of the pike (*Esox*) in the 15th vraison' of the 'Recherches sur les Poissons Fossiles,' the author says 66), "Un os de la tête placé entre le frontal postérieur, le frontal prinal, le pariétal, la grand aile sphénoïdale et l'occipital latéral, ne saurait nais être envisagé comme correspondant à l'apophyse mastoïdienne du nporal. D'après ses liaisons, je crois donc qu'il faut envisager le *mastoïdien* Cuvier comme l'analogue de l'*écaille du temporal* ou comme le *temporal* oprement dit. C'était déjà l'opinion de Spix, qui est tombé juste sur ce nt." To this I reply that, in regard to the connections of the mastoid, those h the parietal, alisphenoid and exoccipital, are more constant than that h the frontal, which is interrupted in mammalia by the interposition of expanded squamosal, peculiar to that class; but the mastoid retains its cine connection with the postfrontal in many reptiles and some birds. On other hand, the union of the squamosal with the frontal is by no means onstant character in mammalia: it is rarely found in the orang, still more ely in man, never in the cetacea and monotremes, nor in certain ruminants, in the myrmecophaga, &c. The connection of the mastoid with the ntal is more common than is the connection of the squamosal with the occipital. It is a bold leap to take from the mammal to the fish in the demination of a variable bone like the squamosal: nevertheless, I would reest the unbiassed reader to glance at fig. 12, whilst he reads M. Agassiz's *écis* of the character of the squamosal above cited, and see how far no. 8 deites from it, save in regard to the frontal connection. Spix, who appears t to have traced the beautiful gradation of the mastoid in the mammalia, d who was unacquainted with the decisive step to its normal condition in oviparous vertebrates made by the monotremes,—and who was influenced, erefore, by seeing that bone in higher mammals pushed back from any conction with the alisphenoid and postfrontal by the interposed squamosal, iich usurps these connections and combines them with others, as with the rietal and tympanic, which the mastoid (no. 8) presents in fishes,—not unsonably concluded that no. 8 represented the squamosal in that class; and is probable that M. Agassiz, who received his anatomical rudiments at unich, and was early engaged in describing the fishes collected in Brazil by e author of the 'Cephalogenesis,' might have derived a bias in favour of this ew which prevented his assigning their due value to the connection of no. 8 fishes with the paroccipital, and its contribution to the otocranial cavity.

* *Op. cit.* tab. iii. figs. 9 and 13, *p*, *q*.

In urging a reconsideration of the value and significancy of these cha- ters, I may repeat that in mammals the mastoid constantly presents t whilst the squamosal very rarely has the first, and not often the second racter. It must also be remembered that the squamosal loses its connec with the frontal and progressively decreases in the mammalian class to less the dimensions of the mastoid itself, as *e. g.* in echidna (fig. 12), whilst in monotreme the mastoid, 8, besides its connections with the parietal and exo pital, extends forwards to articulate with the alisphenoid, 6. If ossifica were restricted in mammals to no. 8, fig. 11, in reference to 16, which mained cartilaginous, then no. 8 would have the same relation to the otocr or in other words, would contribute the same protection to the acoustic la rinth, which no. 8, fig. 5, performs in fishes; the external semicirc canal at least would be protected by the mastoid in both: only in mamm the mastoid would also extend over the posterior canal. The petrosal l no part of its essential character as the capsule or outer tunic of the la rinth by becoming ossified, nor is it less recognisable in fishes within mastoid, by remaining membranous or cartilaginous, than is the scler capsule of the eye in its chamber or orbit; which capsule, in like man presents all the corresponding histological modifications in one or other of the vertebrate series. The mask which has concealed the true feature resemblance of the human mastoid to that of fishes, is simply the petr ossified and cemented to it. But the squamosal presents no such relation the bony capsule of the semicircular canals in any mammal. Even connection of the squamosal with the tympanic bone is, as we have seen, less constant and intimate in mammals than the connection of the mast with the tympanic*.

In the anatomical description of the existing ganoid fishes which Agassiz has unfortunately called 'Sauroid†,' the bone no. 8 is described

* From the remark in p. 53, t. ii. pt. ii. 'Recherches sur les Poiss. Foss.,' it would se that the circumstance of the extension of the tympanic air-cells into the mastoid, in cert mammalia, had weighed with M. Agassiz in determining its homological characters.

† All the characters by which these highly organized fishes approximate the *Reptilia* found, not in the highest, but in the lowest order of that class, viz. in the batrachia, and her more especially in the salamanders. The air-bladder of *Lepidosteus* resembles the lung the serpent in its singleness, and those of the salamander in the degree of its cellulari some parts of the structure being peculiarly piscine. The bifid air-bladder of *Polypte* resembles the lungs of the salamandroid menopome and proteus, in the want of cell walls. The characteristic large bulbus arteriosus and its numerous rows of valves, wh distinguish the ganoids from most other osseous fishes, are retained in the menopome, l are not present in any saurian. The anterior ball and posterior cup of the vertebræ of *Le- pidosteus* are repeated in the salamander and pipa, but in no existing saurian. The lab rinthodont character of the teeth of Lepidosteus was developed to its maximum in the gr extinct reptiles (*Salamandroïdes*, Jäger), which, by their double occipital condyle, der gerous double vomer, and biconcave vertebræ, were essentially *Batrachia*, not *Sauria*; a which combined characters now found only in the lower salamandroid *Batrachia*, with den ones borrowed from fishes, and but feebly manifested by the most fish-like of sauria (*Ichthyosaurus*). All the so-called sauroid fishes retain the characteristic piscine articu concavity on the basioccipital for the atlas: it is, however, very shallow in the polypteru and is also extended transversely, with the lateral borders or angles so prominent, that, M. Agassiz well remarks, "it needs very little to change this transverse articulation with two lateral ridges into two distinct articular condyles," *l. c.* p. 71. But this would conve *pro tanto*, the polypterus into a batrachian, not into a saurian. So far as the character of single convex occipital condyle is valuable as a mark of affinity to the *Sauria*, it is prese in a fish of a different order from the ganoids, and with much fewer approximations in oth respects to the reptilian class, viz. in the *Fistularia tabaccaria*. There remains, therefor only the character of the enamelled scales which the polypterus and lepidosteus present commou with all the lower organized ganoids, and which to a certain extent resemble t bony scutes of the crocodilia. If the deposition of calcareous matter in and upon the sk were not essentially a retention of a very low type of skeleton; if it were not presented l

king part, by its large size, in the formation of both the internal and ex-rnal surfaces of the cranial* box, which size depends essentially on the gree of development of the frontals, parietals and occipitals: it is further ged that the suborbitals ('apophyse jugale') are likewise attached to it; that e preopercular('apophyse styloïde') diverges, and is directed or abuts against ; that, finally, the bone in question (no. 8, fig. 5) is, with the exception of the trosal, the sole part of the temporal bone which takes a direct part in e formation of the cranial box. "D'après ces considérations," M. Agassiz oceeds, "il est impossible de prendre l'os No. 12 [no. 8, in fig. 5], que uvier a nommé *mastoïdien*, pour autre chose que pour la véritable écaille du mporal. Il prend part à la formation de la boîte cérébrale, il donne inser-on à l'arcade zygomatique, enfin, il prête une articulation au préopercule, ıe nous regardons maintenant comme le véritable représentant de l'apo-ıyse styloïde du temporal," *l. c.* p. 63. Admitting, for the sake of the argu-ent, that the preopercular is the homologue of the stylohyal, and that it arti-ılates with the so-called 'écaille du temporal,' which is not the case in the ajority of fishes, yet this would prove more for the 'mastoid' than for the squamosal' character of no. 8, fig. 5. The stylohyal unquestionably articu-tes in many mammals with the mastoid or petromastoid, between which ıd the tympanic it is anchylosed in man, and it rests with M. Agassiz to emonstrate the species in which it articulates with the true squamous part the temporal†.

With regard to the connection with the suborbital chain of ossicles, which I. Agassiz regards, with Geoffroy, as the jugal or zygomatic arch, even dmitting such connection to be the rule and not the exception, all its rce as an argument in favour of the squamosal character of no. 8 will epend on the ultimate decision of comparative anatomists as to the respect-e claims of the upper and lower zygomata in the macaw's skull, for xample (pl. 1, fig. 1), to a special homology with the zygomatic arch in an and other mammals. The orbit in the bird cited, as in other *Psit-cidæ*, is circumscribed below by a bony frame continued from the lacrymal 3) to the postfrontal (12), and thence to the bone (8) which I regard as ıe mastoid. Below this frame, the slender bone, considered by Cuvier as ıe jugal, and by me as the coalesced jugal (26) and squamosal (27), extends om the maxillary (21) backwards to the tympanic (28), and forms a second ch or zygoma. According to the Cuvierian and generally-received view of ıe homology of no. 8 in the bird, the bridge which it sends forward over the emporal fossa to join the above-described inferior boundary of the orbit, ı the macaw, would be the zygomatic process; and that boundary would be hat M. Agassiz calls its homologue in fishes, viz. the jugal or 'arcade zygo-atique.' But what then is the parallel zygomatic arch below (26, 27), con-

any fishes of different grades of organization, and by some, as the sturgeons and siluroids, *g.* under a scattered arrangement, more like that in the crocodiles than is seen in the scale rmour of the typical ganoids, it might have some weight in proving the affinity of such anoids to the highest order of reptilia; but, viewing this character under all its relations, am not disposed to regard it as establishing that affinity more directly, than it would the ffinity of the crocodile to the mammalian genus *Dasypus*. It is for the reasons above assigned ıat I have been accustomed to treat, in my Lectures, of the anatomical characters of the roup represented by the *Polypterus* and *Lepidosteus*, as those of a *Salamandroid*, rather than f a *Sauroid* family of fishes; the characters being carried out in the direction of the batra-hian order by the remarkable genera *Protopterus* and *Lepidosiren*.

* More properly 'otocranial,' in lepidosteus at least.

† In my notes on the osteology of Mammalia, I find that the stylohyal sometimes articu-ates with the petrosal, sometimes with the mastoid, exclusively, as in most mammals, ometimes with the tympanic, sometimes with the paroccipital process: but no instance is ecorded of its articulation with the squamous portion of the temporal.

necting the maxillary with the tympanic, and marked $z^{m'}$ in fig. 7, taf. i. of Hallmann's monograph? If Cuvier had been correct in regarding no. 8 as squamosal, the name 'jugal' ought to have been transferred from the lo zygoma to the upper one (pl. 1, fig. 1, 73) connected with such squamosa the macaw: and with a like consistency the name 'jugal' ought to have b retained for the suborbital chain of dermal bones in fishes (pl. 1, fig. 2, 73) which it had been applied by Geoffroy St. Hilaire, and to which it has b restored by M. Agassiz. But, in truth, there may be clearly discerned in beautiful modification which has been adduced from the *Psittacidæ*, a pr of Cuvier's erroneous homology of the bone no. 8 in the class of birds, and the same time of his accurate homology of the same bone in that of fishes

Is there no significance in the fact of the bone anterior to the orbit, whi we call lacrymal in man down to the lowest reptile, being constantly p forated by a mucous duct? Can we not recognize in this function a glandular relation, as in the commonly thin scale-like character of that bo and its connections in front of the orbit, the repetition of the characters the largest, most anterior, and most constant of the suborbitals in fishes (*ib.* 73 If the rest of that chain be sometimes wanting, but more commonly prese in that class; if it should present the condition occasionally of a strong con nuous bony inverted arch, spanning the orbit below from prefrontal to po frontal, as in the right orbit of the *Hippoglossus* and the left orbit of *Rhombu* ought we to lose our grasp of the guiding thread of 'connections' by bei confronted with a repetition of that condition in the skulls of certain bird caused by a continuous ossification from the lacrymal to the post-front seeing that a diverging bony appendage of the maxillary arch, unknown in tl class of fishes, has there established a second and true 'zygoma' below tl suborbital one? The extension of the ossification from the post-frontal cr of the suborbital arch to the mastoid is, in truth, a beautiful repetition of a ichthyic cranial character, not unknown however in the reptilia; and whil it adds a proof of the mastoidal character of no. 8 in the bird, it reflec reciprocal confirmation of the accuracy of Cuvier's determination of th bone in fishes.

The true signification and homologies of the bones in that interestin class could never have been elicited from an exclusive study of it, howeve extensive, detailed or profound; nor will the feeble rays reflected from an thropotomical reminiscences lend sufficient light in their determination: the can be clearly discerned only by the full illumination of the beams concen trated from all the grades of organic structure. M. Agassiz, descending to the determination of the squamosal in fishes from its characters in man, con cludes that it must be the bone no. 8, fig. 5, because that bone takes part in the formation of the inner as well as the outer walls of the cranial cavity. Bu this protective function is an exceptional one in the squamosal (fig. 6, 27) it is peculiar to that bone only in one class, and, as we have seen, is not con-stant even there; whilst, on the other hand, the mastoid is recognizable from the inner surface of the cranial walls of the highest mammal (in the human cranium where it is impressed with the fossa sigmoidea, fig. 6, 8), and in a still greater degree in that of the lowest mammal (*Echidna*, fig. 12, 8); whilst in almost every mammal, by its coalescence with the outer surface of the petrosal, it closely repeats the protective character in relation to the ex-ternal semicircular canal, which it presents in fishes,—a function which is altogether foreign to the squamosal in every mammal. I have dwelt thus long, perhaps tediously, and it may be thought unnecessarily, on the true characters and homologies of the petrosal and mastoid, because their determi-nation is essential to, and, indeed, involves that of the squamosal and other membernents of the human temporal bone; and we cannot climb to the gher generalizations of anatomical science, except by the firm steps of true d assured special homologies. There are more important subjects than mologies, no doubt; but nothing is more important than truth, in whatever th we may be in pursuit of her.

Orbitosphenoid.—As evidence will be given in the section on 'General omology' that both squamosal and tympanic belong to a quite distinct tegory of bones from the parts of the 'temporal' which have just been scussed. I shall proceed next to the neurapophyses that precede the sphenoid.

As the determination of this bone (6 in all the figures) involves that of e orbitosphenoid (10), which has rarely been mistaken* for any other bone an 6, there remains little to be added in proof of its homology after hat has been advanced respecting the alisphenoid. The most constant aracter of the orbitosphenoid is its relation to the optic nerve, which either rforates or notches it, whenever the ossification of the primitive cartilage membrane holding the place of the bone is sufficiently advanced; which not always the case in fishes, especially those with broad and depressed ads, and still more rarely in lacertine saurians. The recognition of the bitosphenoid is also often obscured by another cause, viz. the tendency in e class *Reptilia*, and especially in ophidians and chelonians, to an extension ossification downwards into the primitive membranous or cartilaginous urapophysial walls of the brain-case, directly from the parietal and frontal nes.

In the fishes with ordinary-shaped, or with high and compressed heads, e orbitosphenoids are usually well-developed: they are, however, reprented by descending plates of the frontal in the garpike; and they are, like the isphenoids, mere processes of the basisphenoid in the polypterus, which thus fers so unexpected a repetition of the human character of the correspond-g parts†. In the cod (fig. 5, 10) they are semielliptic, raised above the prehenoid (9), suspended, as it were, between the alisphenoid (6) and the ontal (11), and bounding the sides of the interorbital outlet of the cranium: e optic nerves pierce the unossified cartilage closing that aperture, immeately beneath the bone itself. In the malacopterous fishes with higher d more compressed heads, the orbitosphenoids are more developed; they are rectly pierced or deeply grooved by the optic nerves, and are pierced also y the 'nervi pathetici' in the carp. The crura of the olfactory ganglions hinencephala) pass out of the interorbital aperture of the cranium by the pper interspace of the orbitosphenoid, into the continuation of the cranial avity which grooves the under surface of the frontal, in their course between e orbits to the prefrontals. The orbitosphenoids protect, more or less, the des of the prosencephalon; and this function, their transmission of the optic erves, their anterior position to the alisphenoids, and their articulation bove with the frontals, establish their special homology from the fish up to an.

In certain fishes a distinct centre of ossification is set up in the median ne of the fibrous membrane or cartilage, closing the interorbital aperture f the cranium, below the orbitosphenoids, and extending forwards as the inerorbital septum. The bone (represented in pl. 1, fig. 5, and in outline in ut 5, at 9') extends downwards to rest upon the sphenoid (5) or presphenoid

* Geoffroy in his memoir on the skull of birds (Ann. du Mus. x.), indicates the orbitosphe-oid at P, fig. 2, pl. 27, as the 'rocher': and Cuvier describes it as part of his 'os en ceinure' in anourous batrachia.

† Agassiz, Recherches sur les Poissons Fossiles, ii. p. 38.

(9), and bifurcates, as it ascends, to join and prop up the elevated orbitos-noids in the perch and carp (not in the cod). The relations of this ossicl[e] precisely those of the part forming the conjoined bases of the orbitospheno[ids] in mammals, and usually called the 'body of the anterior sphenoid,' in th[e] though this is developed from two distinct centres. In the young wha[le] found it supported by a direct extension of the basisphenoid forwards, w[hich] joins the backwardly prolonged vomer, as in fishes. The common bas[e of] the orbitosphenoids is peculiar, as a distinct bone, so far as I know, to fis[hes]. It has been called by Bojanus* the 'basis alarum minorum sphenoidei rostrum sphenoidei'; by Geoffroy 'entosphénal'; and by Cuvier 'le sphén[oïde] antérieure.' M. Agassiz opposes these determinations by the following rema[rks] founded on the embryological researches of the ingenious Dr. Vogt: "In fishes with a short and thick muzzle, the cartilaginous embryonal pl[ate] ('plaque faciale' of Vogt), which serves as the base of support to the pr[os]encephalon and the nasal fossæ, is transformed into an independent bo[ne] "se transforme intégralement en os." It is then, he says, "represented [by] the cranial ethmoid (le *sphénoïde antérieure* of Cuvier), an azygous bone, '[os] impair,' short, of an almost square form, in which are pierced the canals [for] the transmission of the olfactory nerves. But in the fishes with elongat[ed] muzzles, and of which the eyes in place of preserving their primitive late[ral] position at the sides of the mesencephalon are carried forwards in advan[ce] of the cranium between that and the nasal fossæ, the relations of t[he] 'plaque faciale' are necessarily altered: part of the plate remaining in [its] primitive situation is transformed into the 'cranial ethmoid,' the other pa[rt] is carried forwards, but is never transformed into a distinct bone: it r[e]mains cartilaginous as the nucleus of the muzzle; or if, indeed, the ossifi[]cation of the muzzle is completed, it disappears by virtue of the progressi[ve] encroachment of the exterior ossification. This is the reason why fish[es] have never a true 'nasal ethmoid' (the bones called ethmoid by Cuvier a[re] the nasals), but only a cranial ethmoid†." Influenced by the deservedl[y] high authority of M. Agassiz, I adopted his homology of the bone 9′ in th[e] 'Hunterian Lectures on Vertebrata,' delivered in 1844. But since the notes o[f] those lectures were printed, having been charged with the formation of a ne[w] Osteological Catalogue of the Hunterian Museum, I have carefully reconsi[]dered this question. Passing over, for the present, the assertion that the homo[]logue of the 'nasal ethmoïde' does not exist in fishes, I would first observe that if the orbital aperture (or what appears to those who deem the rhinen-cephalic crura to be olfactory nerves, the anterior aperture) of the cranium were homologous with the aperture closed by the cribriform plate in man, then any bony bar or plate tending to close that aperture might be held to be homo-logous with the cribriform plate or crista galli of the ethmoid: but the inter-orbital aperture of the cranium is always bounded laterally, in fishes, by the orbitosphenoid; and the rhinencephala and their crura extend forwards, to a considerable distance in most fishes, before the olfactory nerves sent off from the rhinencephala escape by those perforations in the prefrontals, which are the true homologues of the single foramina of the olfactory nerves in the so-called ethmoid of birds, and of the cribriform foramina in mammals. The inter-orbital groove or canal in the skull of fishes, which is continued from the presphenoidal or interorbital aperture to the prefrontal foramina, is as essen-tially a part of the cranial cavity as is that contracted anterior olfactory chamber of the cranium of mammals, which, in the thylacine, for example, extends forwards, from where the orbitosphenoids sustain the frontals, ex-

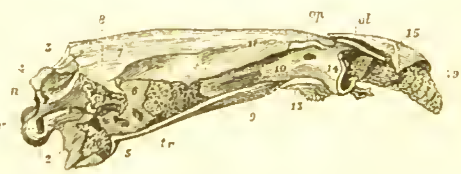
* Oken's Isis, 1818, p. 508.

† Recherches sur les Poissons Fossiles, t. i. p. 120.

iding, to where the frontals and the modified prefrontals (ethmoid) form actual anterior boundary wall of the cranial cavity; the chief distinc-ı between the condition of this boundary in the mammal and the fish, ng, that whereas it is perforated by numerous apertures in the mammal, olfactory nerves in the fish escape each by a single foramen or groove he homologous bones. As beautiful as true was that clear perception Bojanus of the homology of the simply perforated prefrontal of the fish, h its sieve-like homologue in the class in which the olfactory sense reaches maximum of development and activity, and modifies all around it. The lesced bases of the orbitosphenoids, forming the anterior boundary of the l of the optic chiasma, answer to the separate ossification called 'eth-ïde crânien' by Agassiz, in fishes: it has the same relation with that con-cted area of the cranium answering to the interorbital aperture of the cra-m in fishes, which the so-called cranial ethmoid (entosphenoid) presents ishes; and this same entosphenoid (fig. 5, 9′) has as little relation to the mation of the canals pierced by the olfactory nerves in fishes, as the itosphenoid has in mammals. The olfactory, rhinencephalic or anterior ision of the cranial cavity in most fishes has its lateral bony walls incom-te, and it opens freely, in the dry skull, into the large orbital chambers ow, which are then said to have no septum: we see a similar want of de-tion of the cranial cavity in relation to the great acoustic chambers in most es. But in mammals the orbits are always excluded from the rhinence-lic, or olfactory compartment of the cranium*; and a like exclusion ains in some of the highly organized ganoid fishes and in the plagiostomes. the prosencephalic parts of the brain progressively predominate, and the nencephalic parts diminish, in the higher mammals, the compartment of cranium appropriated to the latter loses its individuality, and becomes re and more blended with the general cavity. In the elaborate 'Icono-phy of Human Anatomy' by Jules Cloquet, for example†, the small pe-iarities of the 'trou borgne' and the 'apophyse crista galli' are both in-ated, and very properly; but the rhinencephalic or olfactory division of cranial cavity, though defined by the suture between the orbitosphe-ds and prefrontals and lodging the olfactory ganglia or rhinencephala,— important an evidence of the unity of organization manifested in man's me and traceable in characters, strengthening as we descend to the lowest eous fishes—is wholly unnoticed. Thus, very minute scrutiny, con-cted with great acuteness of perception of individual features, qualities hly characteristic of the anthropotomists of the school of Cloquet, being ected from an insulated point of view, prove inadequate to the apprecia-n of sometimes the most constant and important features of their exclusive ject.

But to return to the homology the orbitosphenoids. In the me-oome these neurapophyses are ngated parallelograms, perfo-ed by the optic nerves, and are tinct bones. In the great bull-g (*Rana boans*) they present a ilar form (fig. 13, 10), but are nfluent with the prefrontals (14): both batrachians an unossified space intervenes between them and the ali-

Fig. 13.



Side view of cranium (*Rana boans*), nat. size.

* This is not to be confounded with the olfactory chamber itself, lodging the organ of ell.

† Manuel d'Anatomie Descriptive, 4to, Atlas, pl. 8, fig. 2.

sphenoid (6). In most lizards the wider roof of the cranium, supported by t long mastoids, squamosals, postfrontals and malars, like a bony scaffolding each side, is independent of its proper (neurapophysial) walls for support, a these retain, through the œconomy of nature, much of their primitive sem membranous, semi-cartilaginous state. A dismemberment of the alispheno (which may be discerned as a process of that bone in the piscine gene *Xiphias*, *Sphyræna*) props up the parietal upon the pterygoid, so like a p or pillar, that the name 'columella' may well be retained for it. At th sides of the membrane forming the orbital aperture, rudiments of the orb tosphenoids may be seen in most lacertia: I find them, *e. g.* in the form a slender osseous filament on each side, slightly bent inwards and bifurca above, in a large Australian lizard (*Cyclodus gigas*). In the crocodile (fig 9, 20, and 22, 10) the orbitosphenoids attain their maximum of developme but retain all their typical characters: they bound the orbital aperture of t cranium; are notched below, as in many fishes, by the optic nerves (*op* are perforated by the pathetic and other orbital nerves at the 'foramen sphen orbitale' (*s*); they protect the sides of the prosencephalon; support above t frontals (and by their backward development also the parietals); and th rest below upon a peculiar development of the presphenoid (9), which seem to answer to the entosphenoid in fishes.

Some salient points of resemblance between the cranial organization of fish and birds have elicited remarks from more than one comparative anatomis Not to dwell upon the more obvious correspondence arising out of the m bility of the upper jaw, chiefly through its connection with the pedicle of th lower jaw, I may indicate the overhanging position of the orbitosphenoi (figs. 8, 23, 10), raised high above the presphenoid (9), at the back part of th interorbital septum: we see exactly the same position of the orbitosphenoi in many fishes. Cuvier accurately represents it in the skull of the perch* This beautiful trait of unity of organization is completely put out of sight b the false homology of the orbitosphenoid in fishes with the alisphenoid i birds and mammals. The progressive recession of the orbitosphenoid an alisphenoid, as we descend from mammals to fishes, transfers indeed thei characteristic nerve-notches or foramina from their posterior to their ante rior margins. But the notch (*op*, fig. 8) at the posterior margin of the orbito sphenoid in the bird for the escape of the optic nerve by a foramen commo to it and the nerves of the orbit, is not less significant of its true homolog than is the anterior notch in the crocodile or fish; the osseous connection with the sphenoid below, with the frontal above, and with the alisphenoi behind, being the same.

Prefrontals.—If the cranium of a cod-fish be bisected horizontally an longitudinally, its most contracted part will be found at the upper part o the interorbital aperture, bounded by the orbitosphenoids, which mark th division between the prosencephalic and rhinencephalic compartments of th cavity: the latter extends as a triangular channel or groove on the unde part of the frontal, opening below into the orbits, gradually expanding as i advances forwards, and dividing into two canals, which diverge to the inter spaces left on each side of the nasal, between it and the bones (fig. 4, 14), that meeting behind the anterior expanded end of the nasal, bound the anterio extremity of the true and entire cranium. The diverging canals of the rhi nencephalic compartment are formed by the two bones in question: the rhinen cephala or olfactory ganglions are sometimes lodged at the extremities of thes canals, and they send out the olfactory nerves by the apertures formed be tween the bones 14 and 15, which then ramify upon the vascular olfactory sacs

* Histoire des Poissons, pl. ii. figg. i. vii. 14.

ported by the bones 19, fig. 5. For the arguments by which the olfactory glions in the cod are shown to be homologous with the olfactory ganglions rest upon the cribriform plate in man, and by which the medullary cords rura connecting them to the rest of the brain are shown to be homologous the so-called 'olfactory nerves' in the human cranium, and for the ge-l homology of both as primary divisions and peduncles of the encephalon, reader is referred to Dr. Desmoulins, 'Anatomie des Systèmes nerveux Animaux à Vertèbres,' 1825, 8vo. t. i. p. 169; to Mr. Solly's excellent tise 'On the Human Brain,' 1836, p. 78; and to my 'Lectures on the tebrata,' 1836, p. 184. I there adopt the expressive name applied by I. Vogt and Agassiz to this most anterior of the four primary divisions he brain of fishes, and apply to the peduncles of the 'rhinencephala,' ch are frequently of great length in fishes, the name of 'rhinencephalic a,' since they are serially homologous with the prosencephalic or cerebral a; and I call that division of the cranial cavity which specially lodges e crura and their lobes the 'rhinencephalic' chamber or compartment. right appreciation of the above essential characters of the most anterior sion of the brain and brain-case is indispensable to the accurate pur-of the homologies of the bones 13, 14 and 15, whose development, espe-y of the pair no. 14, is governed by that of the rhinencephalon. In man all-predominating cerebrum, overarching the mesencephalon and epen-ialon behind, and the rhinencephalon in front, so modifies the surround-cranial bones as to obliterate every part of the rhinencephalic division, the terminal fossa that immediately supports the so-called 'olfactory glia,' which fossa seems, as it were, to be unnaturally drawn in and ded with the great prosencephalic chamber, by reason of the enormous welling development of the proper spines or roof-bones of that chamber, frontals. Still, even here, through the absence of any commissural band necting together the rhinencephala, a fibro-membranous process of the oskeleton extends between them, and into this septum ossification extends n below, called the 'crista galli.' In the cod-fish the homologous parti-between the rhinencephala is cartilaginous, and it extends some way back veen their crura, not being opposed by a coextended overhanging cere-m with great transverse commissures. In many fishes (e.g. *Xiphias*, pl. 1, 5) the outlet of the olfactory nerves, which notches the inner side of 14 in the cod, is converted into a foramen (*ib. ob.*) by the extension of fication around the mesial surface of the nerves. Where the olfactory ves are sent off from the ganglions in great numbers (e. g. *Raia*), they orate a membrane before reaching and ramifying upon the vascular itary sac. In man, the homologous membrane, or basis of the olfactory sules, is ossified, and called from its numerous apertures the cribriform e. The holes which these cribriform plates fill up are homologous with foramina, or grooves forming the outlets of the olfactory nerves in the es no. 14 in fishes (figs. 4 and 5).

The grounds for this homology are so plain that we cannot be surprised they should have been early appreciated, as *e. g.* by the painstaking and osophic Bojanus in 1818*. I never could comprehend the precise mean-of the statement with which Cuvier opposed his view:—"M Bojanus, par-sans doute du trou qu'il a dans plusieurs poissons pour le nerf olfactif, en une lame cribleuse de l'ethmoïde; mais cette opinion, qui n'a pas ce soutien s toutes les espèces, est réfutée d'ailleurs par les autres rapports de cet os les os voisins†." Cuvier seems to have thought the ground of Bojanus's nion to be cut away by the fact that in the cod and some other fishes the

* Isis, heft iii. p. 503.

† Histoire des Poissons, i. p. 235.

olfactory nerves groove instead of perforate the bones no. 14. But the tri minal still determines the alisphenoid, whether it perforates or notches t neurapophysis in its escape: the relation of the alisphenoid to the divis of the 5th, including the gustatory nerve, and that of the orbitosphenoid the nerve of sight, are not more constant than is the relation of no. 14 to t nerve of smell. The differences of connection of no. 14—'les autres ra ports'—are not specified by Cuvier, and I know none that affect its essent character.

No. 14 is however the most anterior of the neurapophysial or late bones of the true cranium, and is in relation with the anterior terminal di sion of the encephalon and with the first or anterior terminal pair of nerv Like all extreme or peripheral parts, it is subject, as we should be prepar to find it, to a greater extent and variety of modifications than the mo central neurapophyses. The difference between its connections in the fi and that of the cribriform plates and their sustaining basis in man m therefore be expected to reach the extremes of possible homology. It w be interesting to inquire whether there are intermediate modifications l which the nature of that difference may be appreciated, and how many such links are permanently retained in the intervening species.

We might anticipate the smallest amount of departure from the fu damental vertebrate type, as respects form, size and connections of the bon in question, in that class where the principle of vegetative repetition mo prevails and the archetypal plan is least obscured by teleological adaptation Adopting the name modified from the phrase applied to these bones by Cu vier in those vertebrata in which they present their most typical character we find the 'prefrontals' in all bony fishes resting below upon the vomer (fig 4 and 5, 13) and on part of the presphenoid (9), sustaining by their mesial an upper surfaces the nasal (15) and fore-part of the frontal (11), affording th whole or part of the surface of articulation for the palatine (20) or the palat maxillary arch, and giving attachment exteriorly to the large suborbital c lacrymal bone (pl. 1, fig. 2, 73), when this exists. Besides their protectiv functions, in relation to the olfactory ganglions and nerves, they close the cra nial cavity and bound the orbits anteriorly. The most constant and charac teristic connections appear to be with the vomer, nasal, palatine and fronta In the murænoid fishes, where confluence begins to prevail in the cranial bone we find that the prefrontals coalesce with the vomer and nasal, not with th true frontal. This fact, though not of a class materially affecting relation of homology, is not devoid of significancy in regard to the real character o the bone usually described as one of the 'deux démembremens du frontal*. A clew not to be neglected in tracing the homologies of the prefrontals i their histological progress, although the value of such embryonic character has been overrated and their application sometimes abused. The substramen of their ossification, like that of the exoccipitals, mastoids and post-frontals is a cartilaginous mass, a part of that which M. Dugés has called 'cartilage cranio-faciale,' and M. Vogt 'plaques protectrices latérales.' The frontal and parietals, being ossified in supra-cranial fibrous membrane with so rapid and transitory a cartilaginous change as to have escaped general recognition, have been, on that account, rejected from the vertebral or endo-skeletal system of bones by Dr. Reichert, and with as little real ground as the rejection of the vomer and sphenoid from the same system, because they are ossified in membrane extended from the under and fore-part of the sheath of an evanescent subcranial 'chorda dorsalis,' like the homologous basal ossification beneath the coalesced anterior abdominal vertebra of the siluroids.

* Agassiz, *op. cit.* i. p. 123.

[. Dugès, who has accurately figured the 'cranio-facial' cartilage of a ›id fish in pl. ii. of his valuable Monograph *, gives as accurate a figure ıe same cartilage in the *Rana viridis* (pl. i. figs. 6, 7, of the same work), of which has been ossified a bone which transmits the olfactory nerve to ·ose-capsule: this bone (15 in the figures cited) rests below upon the di-l vomer and on the end of the presphenoid, sustains above the nasal and part of the frontal, affords an articular surface on its outer part for the ine, and only fails to repeat every characteristic connection of the pre-als in fishes, because (as likewise happens in certain of that class) there › lachrymal bone developed in the *Batrachia*. The sole modification ıy consequence tending to mask the homology is this; that whereas we in many fishes ossification extending into the persistent part of the cra-cial cartilage connecting, whilst it separates, the prefrontals, so as to mscribe the canals for the transmission of the olfactory nerves, such ossi-on proceeds in the anourous batrachia to anchylose the prefrontals with other, and convert them into a single bone. This difference however ed with Cuvier to make of it a new and peculiar bone—an 'os en cein-.'† It would have been as reasonable to have given a new name to the ıoccipital in the *Lepidosteus*, because it is divided in the middle line in-of being single, or to the frontal in the species where it is single instead eing divided, or to the vomer in the frog because it is double instead of e, or to the exoccipitals in the same reptile, which manifest the same il and annular confluence as the prefrontals. But, adds Cuvier, in refer-:to the single bone (fig. 13, 14) resulting from this modification, "Je ne as trouvé divisé, même dans des individus très-jeunes qui avoient encore rand espace membraneux entre les os du dessus du crâne." Nor did the anatomist ever find the rudiments of the radius and ulna distinct at any d of development of the single bone of the *Batrachia*, which he never-ss rightly describes as representing both bones of the fore-arm: nor e ever find a division of the single parietal in the embryo crocodile, ı he equally well recognized, nevertheless, as the homologue of the two tals, which in most fishes have been subject to greater modifications in connections and relative position than the single prefrontal presents in nourous batrachia. These are not the only instances where relations of logy are by no means obscured, nor ought to be, by reason of the con-ce or even connation‡ of essentially distinct elements. The capsule of lfactory organ, partly protected by the anterior infundibular expansions e connate prefrontals, undergoes no partial ossification homologous with turbinal' (19, fig. 5) of fishes, but remains cartilaginous, like the scle-and petrosal.

e prefrontals, however, are not only connate with each other in the but coalesce with the contiguous neurapophyses—the orbitosphenoids g. 13). And this modification has led Cuvier, notwithstanding the ection of the bone 10 with the presphenoid below, with the frontal e, and with the prosencephalon, optic nerve (*op*) and orbit, to charac-the batrachian skull as having "un seul sphénoïde sans ailes tempo-ni orbitaires;" the true and distinct 'alisphenoid' (6, fig. 13), with its al connections and nerve-perforations (*tr*), being described as the pe-

echerches sur l'Ostéologie, &c. des Batraciens, 4to, 1835.

ssemens Fossiles, 4to, t. v. pt. ii. p. 387. He had before applied the name of 'ceinture e' to the scapular arch in fishes.—Leçons d' Anat. Comp. i. (1800) p. 332.

use these terms in the same definite sense as the botanists; those essentially distinct are *connate* which are not physically distinct at any stage of development, those united are *confluent* which were originally distinct.

trosal, 'rocher*.' But the real difficulties which beset the quest of ge truths in comparative osteology are such that we may well dispense with over-statements of the amount of deviation from the cranial archetype w much-modified skulls like those of the anourous batrachia may pre Fortunately the light which the development of such skulls throws their mature characters, is aided by the persistent larval stages manif by the perennibranchiate species.

In the menopome, for example, the prefrontals remain distinct, both each other and from the orbitosphenoids†, their characteristic connec and functions being the same as those of their coalesced homologues in frog, except that they are notched, instead of being perforated by the o tory nerve, which grooves their inner border, as in the cod and some c fishes. Cuvier just hints at the possibility of his 'os en ceinture' in the representing "à la fois le frontal principal et l'ethmoïde‡," or as havin equal pretence to one or the other name.

The suture, however, which marks the limits between the frontal 11 parietal 7 is persistent in the menopome, and indeed in all batrachians the anourans; and even in the very young larvæ of these, Cuvier ad (and the observations of M. Dugés warrant the admission) "que l'on sé une partie postérieure de forme ronde de l'antérieure qui est allongée" (p. 387). The permanently distinct frontals present a similarly elongated f in the urodeles, and are therefore recognized by Cuvier in the salaman *e.g.* at *c*, pl. xxv. fig. 1, *op. cit.*; in the newt, pl. xxvi. fig. 6; in the menopo fig. 4; in the axolotl, pl. xxvii. fig. 24; in the siren, *ib.* fig. 2; and in the phiuma, *ib.* fig. 6. In all these crania the true frontals are indicated by same letter *c*; in none of them do they close the cranial cavity or bound orbits anteriorly, or are perforated by the olfactory nerves, or articulate w the vomer below, or perform any of the essential functions, or combine the racteristic connections of the prefrontals of fishes, all of which concur in 'os en ceinture.' But the frontals do present the chief connections and occ the relative position of the anterior half of the bone (7 and 11, fig. 13) wh Cuvier calls the parietal in the frog. The evident tendency to coalescence essentially distinct bones which pervades the skeleton in the adult anour greatly diminishes the difficulty, through the loss of the suture between parietal and frontal, of recognizing the homology of the latter bone, wh with that exception, not only repeats the characters of the frontals in fis but of those in most tailed batrachians.

Next, then, with regard to the ethmoid, the second of the two bones which Cuvier restricts the choice of the homologues of the 'os en ceintu no. 14. No name has been applied more vaguely or with a less defi meaning than this same 'ethmoïde.' In the sense in which Cuvier wo permit its application in the present instance, it is a bone which forms

* *Op. cit.* p. 386.

† The menopome, which represents a gigantic tadpole of the tailless batrachia, manif a beautiful conformity to the general type, and well illustrates the real nature of the appa deviations which take place in the course of the remarkable metamorphoses of the anour At first sight the orbitosphenoids seem to be barred out from their normal connection w the frontal by the junction of the parietal with the prefrontal in the menopome, as appe for example, in the figure given by Cuvier in the 'Ossemens Fossiles,' v. pt. ii. pl. xxvi. fig where *c′ h* divides *c* from *u*. Remove, however, the prefrontal *h* from the parietal *c′* (wh may be readily done, the suture, which is not indicated in the figure cited, being persiste and the anterior and mesial half of the orbitosphenoid (*u*) is then seen extending inwa (mesiad), beneath the parietal and prefrontal, to join a triangular surface formed by a scending process from the middle of the outer edge of the frontal.

‡ *Op. cit.* p. 388.

terior and antero-lateral walls of the cranium, defends the rhinencephala d transmits the olfactory nerves, but is altogether distinct from and pos-·ior to the capsules of the organs on which those nerves are ramified. the crocodile Cuvier restricts the term 'ethmoid' to the cartilaginous ninæ, capsules, or supports of the olfactory ramifications after the nerves ve left the cranium. In mammals the ethmoid is made to include both the nes that close the cranium anteriorly, support the rhinencephala, give exit the olfactory nerves, and those which defend and sustain the enormously veloped and complex superior parts of the organ of smell*. Whilst this nfusion is permitted to vitiate osteology, it is plain that no intelligible mological or other proposition can be predicated of the 'ethmoid.'

When Cuvier, with reference to the hypothetical possibility of the homo-·ue of the frontal forming part of the bone 7 and 11 in the frog, adverts to second mode of bringing the 'os en ceinture' into the ordinary category cranial bones, by viewing it as the 'ethmoïde,' he adds, that it would then "un ethmoïde ossifié, se que sera une grande singularité" (*ib.* p. 388). re it is obvious that the predominating idea of the ethmoid was that pre-ted to his mind by the capsules of the olfactory organ in the crocodile and er reptiles, which he had so called, and which are wholly or in great part tilaginous. But the parts of Cuvier's ethmoid in birds and mammals, which in functional and physical relation with the cranial cavity, rhinencephala l olfactory nerves, are ossified: the bone, also, to which he gives the name hmoid' in fishes (fig. 5, 15), is ossified; and, what is more to the purpose, bones (14) in fishes, ophidians, chelonians and saurians, which repeat the ential characters of the batrachian 'os en ceinture,' are likewise ossified.

General homology teaches that the bone or bones in relation to the defence the rhinencephala and the transmission of their nerves belong to one class, l that the parts of the skeleton, whether membranous, gristly or bony, ich form the capsule or sustain the olfactory organ itself, belong to another l very different class of parts of the skeleton. But, not to anticipate what ongs more properly to a subsequent chapter of this work, observation ws the two parts to be physically distinct in all vertebrates except mam-ls, and to be distinct in the fœtus of these. Whether we restrict the term hmoid' to the neurapophysis or to the sense-capsule (which in mammals ludes the 'conchæ superiores' and cells of the ethmoid), the term must applied arbitrarily in its extended or homological signification, since the ırapophysis dismisses the nerve, not by a 'sieve-like' plate, but by a single amen or groove in all the vertebrates below mammals. The multiplied amina in the neurapophysial or cranial part of the anthropotomical 'ethmoid,' ence that name, as well as the special designation of the part called 'lamina orosa,' are modifications peculiar to the mammalian class, but not constant e, and they form no essential homological character of the bone in question. ıppears to me preferable, since we have two essentially distinct parts of the leton combined in the mammalian and human ethmoid, to restrict the term moid to the part which appertains to the sense-capsule, *i. e.* which is directly cerned in the support of the membrane and cells of the olfactory organ.

Objecting to Oken's idea, that the prefrontal in the crocodile was homologous with the of the ethmoid called 'os planum' in anthropotomy, Cuvier says, "Or l'os planum ne ıît jamais sur la joue; il ne se montre plus dans l'orbite à compter des makis si ce n'est oetit point dans les galeopitheques et dans quelques chats. Dans tous les autres mam-ères l'ethmoïde est entièrement enveloppé et caché par le palatin" (note that significant nection) "et par le frontal et spécialement par cette partie du frontal dont il est main-ınt question et qui se détache dans les ovipares. Le véritable ethmoïde est enveloppé a même manière dans le crocodile, quoique presque toutes ces parties restent cartilagi-ses."—Ossem. Foss., v. pt. i. p. 73.

But leaving for the present the question of names, and returning to thin; let us pursue our search and comparisons of the bones which continue in t higher classes to repeat the essential characters of those called 'prefronta in fishes. Were it necessary to add to the reasons above assigned for regardi no. 14, fig. 13, as the homologues of 14 in the fish, notwithstanding they a connate in the batrachian, I would cite the structure and relations of the bones in the sword-fish. The whole of the anterior part of the extensi interorbital space is occupied by the prefrontals (Pl. I. fig. 5, 14) which jo each other at the median line by an extensive vertical cellular surface: th form the anterior border of the orbit, and the posterior wall of the nasal foss they close the cranial cavity anteriorly, and each transmits the olfacto nerve to the capsule by a central foramen. They are almost covered by t frontals (11) above, which they support by a broad flat surface; a very sm portion only appearing on the upper surface of the skull at the anterior ang of the orbital ridge. Were the frontals separated, the prefrontals would th appear, as in the frog, at the median line: were the suture between the tw prefrontals to be obliterated in *Xiphias*, an 'os en ceinture' would be pr duced like that of the frog. The nasal bone of the sword-fish, which Cuvi calls 'ethmoïde,' presents a cellular structure of its base (15, *ns n*) design to break the force of the concussion arising from the blow which is deliver by the 'sword.' But the prefrontals manifest more extensively this peculi cellular structure, which Cuvier well says, "l'on prendrait presque pour l cellules de l'ethmoïde d'un quadrupède*."

Cuvier, not perceiving or not appreciating the grounds of the homology the 'os en ceinture' with the prefrontals, describes the divided nasal (15, fi 13) in the batrachia as the 'frontaux antérieures'; and reciprocally, havi called the bones in fishes, homologous with the bone 14, (which he thoug might represent the ethmoid in the frog) 'frontaux antérieures,' he gives th name 'ethmoïde' to the bone 15, fig. 5, whether single or divided, in fishe It is not necessary to add anything to the arguments by which M. Agass has sustained the conclusion of Spix, that Cuvier's 'ethmoid' in fishes is th 'nasal.' And it needs, I think, only to compare the connections of th bones 15, fig. 13, with either the single or the divided nasals in fishes, and t glance at the obvious homology of the bones *h* in Cuvier's pl. xxiv. fig. 1—(with the bones *g g* in figs. 4 & 6 of pl. xxvi. ('Ossemens Fossiles,' t. v. pt. 2 to ensure the acceptance of the conclusion, that his 'frontaux antérieure in the frog and the other anourans are the true nasal bones.

The membranous and cartilaginous basis of the lateral walls of the craniu especially of its anterior compartments (prosencephalic and rhinencephalic are incompletely ossified in all lacertian Sauria. The orbitosphenoids ar represented in most by small styliform ossicles ('Ossemens Fossiles,' t. v pt. 2, pl. xvi. fig. 1, *z*) bounding the anterior and inferior part of the prosen cephalic chamber, and which Cuvier, who describes the true alisphenoid a the petrosal (rocher), regards as the representative of both alisphenoid an orbitosphenoid. The alisphenoid is, however, well characterized by its con nections with the basisphenoid and exoccipital, with both of which it com monly becomes anchylosed; by the share which it contributes to the cham ber lodging the true cartilaginous 'petrosal'; and by the notch on its fore part for the escape of the third division of the fifth nerve.

The orbits and rhinencephalic groove are bounded anteriorly and divided from the olfactory compartments by two transversely extended and antero-posteriorly subcompressed bony columns, resting upon the palatines below

* Hist. des Poissons, t. viii. p. 194.

d arching upwards and backwards, expanding as they ascend, and defining ternally the membranous space perforated by the olfactory nerves. These the parts in all lizards that repeat the essential characters of the prentals in batrachians and fishes: they are, moreover, distinct from one aner, and appear on the upper surface of the skull anterior to the frontals, d thus resume their more typical character as first displayed in fishes. In large monitors ('Ossemens Fossiles,' v. pt. 2, pl. xvi. fig. 1, *e*) there can no mistake as to their special homology; since they articulate with the chrymals (*f*) (homologues of the great anterior muco-dermal suborbital ne), and also, as in the carp, with a supraorbital ossicle (*h*): but in many ier lizards and in serpents they are confluent or connate with the lachryals. In this case the external antorbital position and perforation for the icous duct distinguishes the lachrymal portion of the coalesced bones. In python the broadest part of the palatine, formed by the process directed vards and by the opposite one sent outwards for the suspension of the axillary, articulates with the under surface of the prefronto-lachrymal bone; d the inner part of the true prefrontal portion is notched by the olfactory rve in its passage to the capsule supported by the ossified turbinal*.

The bones, which more resemble the anchylosed prefrontals in the frog, are frontals of the python; but the resemblance is confined to one character ly, and that an exaggeration of a character common to the frontal bones of any birds, and of the ornithorhynchus among mammals, viz. a developent of a median bony partition from the line of the frontal suture into the edian interspace of the encephalon. In the python each frontal sends wn at the fore-part of this suture such a partition, which is therefore double, the falx essentially is in man and the mammalia, in which it retains its imitive histological condition of a fibrous membrane. The ossified laminæ the falx in the python bend outwards and coalesce below with the external orbitosphenoidal plates of the frontal, and thus surround the lateral divins of the fore-part of the brain (rhinencephala), which are drawn back the progress of the concentrative movement of the cerebral centres, so as occupy the prosencephalic segment of the cranium, the prosencephai being, in like manner, protected chiefly by the mesencephalic bony arch. ie change is precisely analogous to that which takes place at the opposite tremity of the neural axis in higher animals. In the python every segment the spinal chord retains its primitive relation to the segment of the endoeleton, through which it transmits its pair of nerves. In the mammal the ncentrative movements of the spinal chord draw its hinder segments in vance of their proper vertebræ, and the primary relation is indicated by nerves which these vertebræ continue to transmit, and by which alone we guided from the segment of the endoskeleton to that of the neural axis iich originally governed its development.

Accordingly, at the anterior end of the skeleton, we trace the relation of osseous segment, which transmits the olfactory nerves to their caple, to its proper division of the neural axis, by following those nerves back the retracted ganglions (rhinencephala) from which they take their origin. ie connections of the annular frontals of the python with the parietals and st-frontals behind, with the connate orbitosphenoids, and through them with presphenoid below, prevent their homology being mistaken; for they are from completely representing or repeating the essential characters of the alesced annular prefrontals of the frog.

Not to lengthen unnecessarily this exposition of the homologues of the pre-

* In my 'Report' I was misled by the confluence of the true prefrontals with the lachryls to view the turbinals ('cornets inférieures' of Cuvier) as the homologues of the prentals in the python.—Report of British Association, 1846, p. 220.

frontals (14, figs. 4 and 5) in fishes, I pass at once to the highest of existing re tiles, the crocodile. Here we find, in the dry skull, the condition of the crani cavity in the fish beautifully and closely repeated: the prosencephalic pa opens freely by the aperture bounded by the orbitosphenoids (fig. 9, 10) in the common orbital cavity (*or*), and the rhinencephalic division of the craniu is prolonged, as a groove upon the under surface of the coalesced fronta (*ib.* 11) above the orbits, expanding as it advances, until it is arrested by boundary formed by two bones (*ib.* 14), which rest below upon the vom and give attachment there to an ascending process of the palatines (20), whic sustain by their mesial and upper expanded surfaces the nasal (15) and for part of the frontal (11); and articulate exteriorly with the large lachrym bone (fig. 22, 13) perforated as in the fish and lizard by a mucous duct fro the orbit. They are each grooved on their inner or mesial surface (indicate by the numerals 14, in fig. 9) by the olfactory nerve, where it escapes fro the cranium to spread upon the membranes sustained by the cartilaginou capsules anterior to the bones in question; below these grooves the bone (14) extend inwards and meet at the mesial line; but do not coalesce ther as in the frog, nor extend their mesial union upwards, so as to convert th olfactory grooves into two complete canals. They, therefore, retain or resum much more of their primitive piscine character than do their homologues i the frog, and manifest it conspicuously by developing a subtriangular externa plate which appears on the upper surface of the cranium at the anterior angl of the orbit between the frontal, the lachrymal and the nasal bones. In short the homology of the bones 14 in the crocodile (figs. 9, 21, 22) with thos so numbered in the fish (figs. 4 and 5), was quite unmistakeable; and, wit the exception of Spix, all anatomists have concurred in this respect wit Cuvier: only some of them have extended further and expressed differentl the homologies of the bones in question.

Now, bearing in mind the small brain of the cold-blooded crocodile, and the concomitantly restricted development of the spine or roof-bone in specia relation with the cerebrum, viz. the frontal (11), which is aided in its secondary function in relation to the orbit by distinct supraorbital bones in all crocodiles, and contrasting the condition of the part of the brain which chiefly governs the development of the frontal bone with that of the same division of the brain of mammalia,—let us proceed to make the comparison which Cuvier recommends*, in order to trace the homologues of the crocodile's prefrontals in the mammalian class.

We place the skull of a ruminant (the red deer, *e. g.*) by the side of that of a crocodile, and delineate a suture which would detach a portion from the frontal, having the same superficial connections as the upper peripheral plate of the prefrontal has in the crocodile. It appears to be far from presenting the same figure; but most assuredly such artificially detached portion of the ruminant's frontal has not the same functions ('emploi') as the prefrontal has in the crocodile. For if we even include with the part so detached the anterior portion of the descending orbital plate of the frontal, we find it joining below the orbitosphenoid without any connection with the vomer, or any attachment to the palatine: it forms no immediate part of the supporting plate of the rhinencephalon, nor of the foramina for the exit of the olfactory nerves. Such artificially detached portions of the mammalian frontal are entirely separated from each other; whilst one of the important

* "Il suffit en effet de placer une tête de mammifère, de ruminant par exemple, à côté d'une tête de crocodile, pour s'assurer qu'il s'est fait ici ('du frontal antérieur') un démembrement du frontal. On pourroit, sans rien déranger, dessiner sur le frontal du mammifère la suture qui existe dans le crocodile, et on détacheroit ainsi dans le premier un frontal antérieur qui auroit la même position, presque la même figure, et absolument le même emploi que dans le crocodile."—Ossem. Fossiles, v. pt. ii. p. 73.

its of resemblance between the prefrontals of the crocodile and those of fish are the mesial approximation and junction of their descending (neurophysial or rhinencephalic) plates—the most constant and important parts he bones in question.

f the frontal of the ruminant or other mammal were expanded only at parts corresponding with the detached bones called "frontaux antérieures" in the crocodile, there might then be a *primâ facie* probability that 1 expansions were connate parts, dismembered in the crocodile's skull. the vastly increased lateral as well as anteroposterior development, and more or less vertical convex expansion of the frontal in the highest ebrate class, naturally indicate, in the first place, an inquiry into the comitant modification of the nervous centres by which the development hat bone is mainly governed; and if such modification should then be id to exist, in the cerebrum, for example, which, from the ascertained elative progress of the frontal in other classes, ought to cause or be ciated with such a general development of that bone as characterises the l in the mammalian class, it must surely be superfluous and gratuitous xplain that development by the hypothesis of a coalescence of another ntially distinct element of the cranial parietes: especially if that element roved, by a similar tracing of its relations to the progressive development he cerebral centres, to have as essential and exclusive a dependence 1 the rhinencephalon as the frontal bone has upon the prosencephalon. he position of the upper peripheral part of the prefrontal in the situation hich it is seen in the crocodile, is, in fact, the least constant and important of the characters of that bone. In the bull-frog, for example, the ex- d part of the prefrontal is mesiad of the conjoined parts of the nasals frontals instead of being lateral: in the sword-fish the prefrontals barely ear, and in the python they do not appear at all, upon the upper surface ne skull; but they retain in each their more typical neurapophysial po- n, with all their more constant and essential characters. The enormously loped frontal of the mammal masks these characters, and usurps the constant and least important one, viz. superficial position, on which alone ier insists as proving the prefrontal of the crocodile, with its complex tions and connections, to be such a dismemberment of the true frontals e ruminant, as may be marked off with the pen on the upper surface of skull!

he descending [rhinencephalic] plates of the prefrontal in the crocodile 9, 14) are subcompressed in the axis of the skull, and expanded laterally, cially at their upper part; where, in the alligator, I find them forming a ow cup, concave forwards for the lodgment of the cartilaginous olfactory ule,—of that part, namely, which is ossified in mammalia, and there de- ped into the great labyrinth of the superior turbinals and ethmoidal cells. vertical plates, continued forwards from the prefrontals, which extend e to the nasal suture and descend into the vomerine groove below, to aid rming the 'septum narium,' are cartilaginous in the crocodile: they are e or less ossified, and form the 'lamina perpendicularis ethmoidei' in imals. The median plate, dividing the olfactory nerves at their exit, and loped backwards as a partial septum of the rhinencephalic chamber of cranium, and continued into the simple interorbital septum of the croco- also remains cartilaginous: when ossified in mammals, it forms the sta galli.' Now not one of these cartilaginous representatives of the parts he compound bone called 'ethmoid' in anthropotomy, is united or con- ed with the portions of the frontal in mammals which Cuvier has assumed e the homologues of the prefrontals in the crocodile; those bones being

in that reptile, as the prefrontals are in fishes, chiefly concerned in clos
the anterior end of the cranial cavity, in giving exit to the olfactory ner
in suspending the palatine arch, in connecting the vomer with the nasal v
tically, and the nasal with the frontal and lacrymal horizontally, repeating
the crocodile for the latter purpose the development of the upper or horizo
plate which had almost or entirely disappeared in some of the interven
forms of reptiles. In most chelonians this portion of the prefrontal coales
or is connate with the short nasal: but I have found the instructive except
presented by the existing freshwater tortoise (*Hydromedusa*) of the persist
suture between the nasals and prefrontals, repeated in two fossil cheloni
(*Chelone planiceps* and *Chelone pulchriceps*)*.

Proceeding in the ascensive track of the homologies of the prefront
I have selected from the class of birds the skull of the ostrich (figs. 8 and 2
the representative of an aberrant order, in which every deviation from
type of the class that has been supposed to tend towards the *Mammalia*, te
equally or more towards the *Reptilia*†, and in which, conformably with
lower development of the respiratory system, the original sutures of
cranium, or in other words, the signs of the vertebrate archetype on whic
is constructed, are longest retained. Were we to cut off the corresponding
terior angles of the frontals, no. 11, to those supposed to represent in mamm
the bones we are in quest of, we should have even fewer of their charact
than in the higher class alluded to, because the descending orbital plat
less developed, and the frontal, though its general size is much augment
retains more of its oviparous horizontality as an expanded spine or roof-b
of the cranium.

There is a large bone (fig. 23, 73) bounding the anterior border of the or
and from which, as we have seen in the parrots, ossification sometimes exte
backwards along the inferior contour of the orbit to the postfrontal. But t
bone, besides its repetition of the connections of the lacrymal in the fish a
crocodile, resting as in the latter animal upon the true malar bone, is eit
perforated or grooved by the lachrymal duct, which it defends in its cou
from the eye to the nose, and has none of the essential characteristics of
prefrontal. But we see on the exterior of the skull of the ostrich and ot
struthious birds‡, a distinct rhomboidal plate of bone interposed between
frontals and nasals, precisely in the situation in which the upper surface
the coalesced prefrontals appears in the skull of the frog and other anour
batrachians. In a nearly full-grown ostrich's skull, I removed the left fr
tal, nasal, lacrymal and tympanic bones, and the zygomatic arch, as in fig
and found the facet in question to be the upper and posterior expand
surface of a large irregularly subquadrate compressed bone (*ib.* 14), consi
ing of two vertical compact plates coalesced at their periphery, and includi
a loose cancellous texture. The upper and posterior expanded surface of t
bone extends a short way back beneath the frontals, descends and closes t
anterior aperture of the cranium, and sends out from each side a plate
bone which arches over the olfactory nerves and forms the canals by whi
they are conducted along the upper part of the orbits. The anterior and up
surface of the bone again expands (at 14′, figs. 8 and 23), and there sustai
and is covered by, the nasal bones, and again overarches, and is sometin

* Report on British Fossil Reptiles, Trans. Brit. Assoc. 1841, pp. 169, 172.

† The urinary bladder and intromittent organ, *e. g.*: the modification of the feathers
the *Struthionidæ* is a degeneration of a peculiarly ornithic character; but not, therefore,
approximation to the hairy covering of mammals.

‡ In the emeu (*Dromaius ater*) at 14, fig. 1. pl. 39. Zool. Trans. t. iii.: and in the cas
wary at *h*, fig. 3, taf. i. in Hallmann's 'Vergleichende Osteologie des Schläfenbeins.'

-forated by the olfactory nerves (the course of which along the rhinen-)halic continuation of the cranial cavity, is shown by the arrows, *ol.* 14, ;. 8 and 23) prior to their final expansion on the olfactory organ; the in body of the bone forms the fore-part of the interorbital septum and back part of the nasal septum, a slight outstanding ridge or angle iding the two surfaces: it rests below upon the rostral prolongation of presphenoid, which, however, barely divides it from the semicylindrical)oved vomer (13) which sheathes the under part of that process. The terior extremities of the palatines develope broad horizontal plates mesiad l upwards (fig. 23, 20), which join the lower border of no. 14, where it rests on the presphenoid. The outer margins of the anterosuperior expansion no. 14 come into contact with the lacrymals: the posterior border of the tical or rhinencephalic plate joins and soon coalesces with the orbitosphe- ds (10). Thus we have all the essential characters of the prefrontals in fish, the frog and the crocodile, with a repetition of their first important dification in the tail-less batrachians, viz. that of median confluence; and s not unimportant to observe that this is associated with the obliteration of ner cranial sutures, by which also those batrachians resemble birds. The t step in the progress of this median approximation of the prefrontals, is development of the plates which, in certain fishes, convert the olfactory ooves into foramina; these mesial plates next come into contact at the middle e, *e. g.* in *Xiphias* and *Ephippus*; they proceed to coalesce in the frog, and prefrontals are so much further compressed in the bird that the olfactory ooves open upon the outer or lateral instead of the inner or mesial surfaces of rhinencephalic plates: they are, however, very deep grooves in the ostrich, l in the apteryx are canals protected by a distinct external plate. The erruption of the direct vomerine connection by the prolonged presphenoid the chief secondary modification of the prefrontals in the bird. No other ne in the bird's skull repeats the more essential characters of the prefrontals ishes and reptiles, save the bone no. 14, figs. 8 and 23. Cuvier calls this bone 'ethmoïde'; but blames the clear-sighted and consistent German anato- sts who applied that name to the prefrontals in fishes and reptiles; yet the t of Cuvier's ethmoid in the bird answering to the 'lamina cribrosa' of the mmal, sometimes gives passage to the olfactory nerve by a single foramen, netimes by merely a groove, a difference which does not prevent him opting the homology here, though he opposes it to the adoption, by janus, of the homology of the same part in the fish (*ante*, p. 215). The ooth plate forming, with the orbitosphenoid, the interorbital septum, is 'os planum,' or papyraceous plate of the bird's ethmoid, with Cuvier: masking of this part in most mammals by the downward development the orbital plates of the frontal, offered no difficulty to the ethmoidal de- rmination of no. 14 in the bird; and it forms as little valid objection to en's mode of expressing the ethmoidal homology of the prefrontals in the ld-blooded ovipara.

For the reasons before assigned, viz. that the terms 'frontal antérieur' d been given to the bone in question, no. 14, in those animals in which it viates least from its general type, as the nasal neurapophysis, I retain the me 'prefrontal' for it under all its metamorphoses. Cuvier, after balancing e characters of the bones nos. 15, 22 and 73 (fig. 23) in birds, inclines to the inion that 15 is the true nasal, and 22' an essential part (nasal process) of e premaxillary: with regard to 73, he says, "les os externes et plus voisins l'orbite seraient presque comme on le voudrait, ou des frontaux anté- 'urs ou dès lacrymaux." In which case, no. 14 having been described as e 'ethmoid,' one or other of the above-named bones would be wholly absent in birds. "Ce que pourrait faire croire que c'est le frontal antérieur c manque, c'est que dans les oiseaux il n'y a point de frontal postérieur, et q la paroi antérieur de l'orbite, à l'endroit ou le frontal antérieure se trou ordinairement, est manifestement formée en grande partie par une lai transverse de l'ethmoïde*." But the postfrontal is not always absent birds: it is present as a distinct bone, though small, in the emeu's sku figured in the 'Memoir on the *Dinornis*' above-cited; and it is still mo developed in that remarkable extinct (?) genus of wingless birds. Besid to anticipate the subject of a subsequent chapter of this work, a parapophy always disappears from a typical segment of the skeleton sooner than neurapophysis. The rest of Cuvier's difficulty in the recognition of the pı frontal in birds was more nominal than real.

The ethmoid, in the restricted sense in which Cuvier applies the term in th crocodile and other animals with divided prefrontals, and in which I wou apply it in those animals also in which the prefrontals have coalesced, present but remains cartilaginous in the bird. In the mammal it becom bony and contracts anchyloses not only with the still more reduced debris the coalesced prefrontals, but also,—in consequence of the change of positic of the prefrontals through the further progress of concentration, wherel they are drawn backwards closer to the prosencephalic part of the craniu and in consequence of the concomitant expansion of the true frontals,—wit the orbital plates of the frontals; and accordingly these plates usurp in mo mammals the office and the position of the external parts of the prefronta in the cold-blooded vertebrata†.

The posterior part of the coalesced prefrontals (figs. 24 & 25, 14) divid the anterior aperture of the cranium into two outlets, upon the inner circum ference of which the rhinencephala rest; each outlet being commonly close by part of the olfactory capsules, which are ossified and perforated to recei the divisions of the olfactory nerves. When the prefrontals extend backwar and beyond the cribriform plates, they form what is termed the 'crista galli this exists in comparatively few mammalia; but is as large in the seal trib as in man. In the tapirs the prefrontals expand above and overarch the o factory capsules, but their upper horizontal plates are overlapped by th nasals and true frontals. In the *Delphinidæ*, where the olfactory capsul are absent, the prefrontals expand posteriorly, and diverge from their media coalesced portions constituting the septum of the nasal passage, in order t form the posterior boundaries of those passages and the anterior wall of th cranial cavity. They again expand and form a thick irregular mass anterio to the nasal passages in some *Delphinidæ*, and in *Ziphius* ossification extend along the fibrous continuation of the prefrontals forwards to near the end o the premaxillaries‡. They are connate with the orbitosphenoids behind, an soon coalesce with the vomer below; they rise anterior to the frontals an support the stunted nasals which are wedged between the prefrontals an frontals. The cetacea are the only mammalia in which the prefrontals appea upon the exterior of the skull, and which in this respect resemble the reptilia

* Leçons d'Anat. Comp. 1837, t. ii. p. 580.

† Cuvier takes this ground in objecting to Oken's ethmoidal homology of the prefronta in the crocodile, and says, "the ethmoid coexists in a cartilaginous state with, and is enve loped by, the prefrontal, 'comme la partie antérieure du frontal enveloppe l'ethmoïde de ruminans.'"—Hist. des Poissons, v. p. 235. The correspondence is exaggerated, but i matters not. There are other characters of the mammalian ethmoid, as the closing of th cranium anteriorly, the transmitting the olfactory nerves, &c., which are nowise manifeste by Cuvier's cartilaginous 'ethmoïde' in the crocodile, and are very satisfactorily so by th prefrontals in that animal.

‡ Ossem. Foss. v. pt. i. p. 351.

Cuvier describes the posterior and superior expanded and diverging plates the prefrontals as "la lame cribreuse de l'ethmoïde:" the coalesced part rming the septum, he ascribes to the vomer*. Dr. Köstlin†, also, who gards the ethmoid as no proper bone of the skull, but only an ossified gan of sense, yet describes, after the anthropotomists, the coalesced prentals as the cribriform and azygos processes of the ethmoid ('Siebplatte' d 'Scheidewand des Siebbeins,' pp. 85. 89) in cetacea which have no gan of smell. In a young balænoptera, in which the frontals, the vomer d the nasals were ossified, I find the prefrontals as two cartilaginous plates, tending from the nasals above to the groove of the vomer below. In the natee the essential parts of the prefrontals which close the cranial cavity teriorly, and give exit to the olfactory nerves, are thick and unusually panded. But in no mammal do these parts, with their continuation, the mina perpendicularis,' which, as the coalesced neurapophysial plates of efrontals, brings the vomer below in connection with the nasals above, er undergo such modifications as to obliterate their true and essential hological characters.

In proceeding next to consider the special homologies of the bones of the ch closed by the premaxillaries (22) and constituting the 'upper jaw,' I mmence with the palatines (20), because they form, throughout the vertete series, the most constant medium of suspension of that arch to the terior cranial segment formed by the vomer, prefrontals and nasal. This ecret affinity,' as Goethe would have termed it, before the knowledge of general type had revealed its nature, is manifested by the process of the latine in man, which creeps up, as it were, into the orbit to effect its wonted ion with the prefrontal, to that part of the bone, viz. of which Cuvier had cognised the homologue in his 'ethmoïde' of the bird‡. It is the very nstancy, indeed, of these and other connections which has exempted the latine from the different determinations and denominations attached to ier bones, and which renders further discussion of its special homology necessary here.

Passing over, for the same reason, the maxillary (21) and premaxillary (22), d referring to the excellent treatise by Dr. Köstlin§ for the grounds of determination of the 'pterygoid' (24), I proceed to notice other bones ich, diverging from the maxillary arch, serve to give it additional fixation d strength in the air-breathing vertebrates. The first of these is the malar ne (fig. 11, 26), the homology of which has been traced without difference opinion throughout the mammalian class; where, however, the inconstancy its proportions, number of connections, and very existence, is sufficient to dicate its comparative unimportance as an element of the maxillary arch. is absent in many insectivores (*Centetes*, *Echinops*, *Sorex*): it has not en detected as a distinct bone in the zygomatic arch in the monotremes, on count perhaps of its early coalescence, as in birds, with the maxillary g. 12, 21, 26): in *Myrmecophaga gigantea* and *Manis*, it projects backrds, as a styliform appendage, from the maxillary, but does not attain the uamosal; whilst in the sloths and their extinct congeners the gigantic gatherioids, the malar presents its maximum of development and complex-||. In the *Delphinidæ*, again, the malar is much reduced: its slightly exnded maxillary end forms part of the orbit and joins the frontal; the rest tending backwards, as a very slender style, beneath the orbit to the squa-

* Ossem. Foss. v. pt. i. pl. xxvii. fig. 3, *h*.

† Der Bau des Knöchernen Kopfes, p. 11.

‡ See the passage above quoted from the 'Leçons d'Anat. Comp.' ii. p. 580.

§ *Op. cit.* p. 328.

|| Description of the *Mylodon robustus*, 4to, p. 19.

mosal. The malar joins the post-orbital process of the frontal in the *Ma tus senegalensis*, the hippopotamus, the solipeds, and ruminants, some car vores and the lemurs; in the true quadrumanes and man it joins the alispl noid, and sometimes also the parietal.

The presence, form and connections of the malar are much more const in the class of birds; where, however, it must be sought for as an indep dent bone at an early period. In the young ostrich (fig. 23, 26) it is reduc to the form of a simple, straight, slender style, and coalesces first with t similarly-shaped squamosal (27), and next with the malar process of t maxillary (21″). In the crocodile the malar bone (fig. 22, 26) becomes mo developed, and adds the connections with the postfrontal (12) and the ect pterygoid (24′) to the more constant ones with the maxillary (21) and squ mosal (27), which alone sustain it in birds. In most of the chelonians t malar presents the same connections as in the crocodile, but is transmut from a 'long' to a 'flat' bone. It retains the expanded shape in the agam but in most other lizards it resumes the styloid form; being broadest, ho ever, in those genera, *e. g. Iguana, Thorictes, Tejus*, in which it extends fro the maxillary to the postfrontal and squamosal; in the *Varani* it projec freely backwards, like a styliform appendage of the maxillary, as in tl toothless mammalian *Bruta*, above-cited.

There is no malar bone in ophidians and batrachians. The lower portic of the tympanic pedicle in the *Anoura* sends forward a process which joins backward prolongation of the maxillary: in all other batrachia the low portion of the tympanic pedicle is restricted to its normal connections and t its function of affording articulation to the lower jaw. With regard, ther fore, to the zygomatic modification of this portion of the pedicle in anourou *Batrachia*, some may deem it the homologue of the malar; and, in marsu pial quadrupeds, the malar actually forms part of the glenoid cavity for th lower jaw: or it may be regarded as the squamosal, which constantly su ports the lower jaw in mammals: or it may be viewed as the coalesced homo logue of both bones: or finally, as a simple modified dismemberment of th tympanic pedicle of the higher reptiles and birds; effecting a union wit the maxillary bone which makes it analogous to, but not, therefore, homolo gous with, the distinct malar and squamosal in those higher vertebrates. Thi is a question of special homology on which I am unwilling at present t express a decided opinion: but viewing the inconstancy of the squamosal i reptilia, and its deprivation of the function of exclusively supporting th mandible in all ovipara, I am disinclined to adopt the idea of its sudden resti tution to that mammalian function in frogs and fishes; yet, if either of th bones 26 and 27 are to be selected as the homologue of the hypotympanic (28*d* of batrachians and fishes, I should regard the claims of the squamosal to b stronger than those of the malar, which Cuvier has chosen. The further sub division, however, of the tympanic pedicle in fishes, prepares us, in the as censive comparison, for the simple division of the pedicle in batrachia, an for recognising in the lower articular portion a vegetative dismemberment o 28 in the crocodile.

The characters and chief changes, in respect of connections and functions of the squamosal (27) in the mammalia have already been noticed in the dis- cussion of the homologies of other elements of the complex 'temporal bone' in that class. In birds the bone (fig. 23, 27) undergoes the same change of form which has been noticed in the jugal, viz. from the squamous to the styloid. It continues, however, to connect the malar with the tympanic as it does in figs. 11 and 12, but it has no connections with other bones. Cu- vier having been led to recognise the squamosal in the mastoid (fig. 23, 8) of ds, does not distinguish 27 from 26, the true 'jugal:' and Geoffroy viewing ' 'portion écailleuse' of the temporal in that cranial bone of the bird, which figures under the letter R, fig. 17, pl. 27 (Annales du Muséum, x.), calls · true squamosal, the original separation of which from the malar he had ;iced in the chick, 'jugal postérieure.' He did not admit that this division the zygomatic style was constant or common in the osteogeny of the skull birds: but I have always found such division in the embryo, and it con-ues longer than usual in those very species, *e. g.* the duck and ostrich ;. 23, 26, 27), in which Geoffroy denies its existence (*l. c.*, p. 361). Oken :urately describes the two constituents of the zygoma in the skull of the ›se, in his characteristic and origiual Essay*, where he calls the posterior ce (27) the humerus, and the anterior one (26) the radius of the head. janus†, who also recognised the fact of the essential individuality of the ıe (27) in birds, but who saw the homologue of the squamosal rather in the ıpanic (28), calls it 'os zygomaticum posterius.' I could cite other testi-nies to the primitive existence of the distinct bone in birds connecting the lar with the tympanic; but the fact which chiefly concerns us here is, that :he special homology of no. 8 with the mastoid, and that of no. 28 with tympanic be proved, we then have a bone presenting the most constant ınections of the squamosal in no. 27: if, however, that name be transferred, ıas been done by Cuvier, Bojanus‡ and Geoffroy, to other bones, then a r bone and a new name must be introduced into vertebrate craniology, which, as I trust I have shown, there is no sufficient ground.

3oth Oken and Bojanus rightly discern in the permanently distinct bone ch. in the crocodiles (fig. 22, 27) and chelonians, connects the malar (26) h the tympanic (28), the homologue of the bone they call 'cranial hume-,' or 'zygomaticum posterius' in the bird. Cuvier is more accurate in his ermination of this bone (fig. 23, 27) as the 'squamosal' in reptiles; but in at the expense of his consistency in regard to the characters of his ıamosal in the bird: for the homology of no. 8 (Cuvier's 'squamosal') in .22 with no. 8 (Cuvier's 'mastoid') in fig. 23, is as obvious and unmistake-: as is that of no. 27 (Cuvier's 'squamosal') in fig. 22 with no. 27 (his dis-mberment of the jugal) in fig. 23. The squamosal is relatively stronger in codiles than in birds, and in many chelonians resumes its flat, scale-like n; although, as Cuvier well observes, it answers, in function, only to the omatic part of the mammalian squamosal:—" c'est un temporal dont la tie crâniale a disparu§." In lizards the squamosal again resumes the zy-ıatic or styloid shape, connecting the mastoid and tympanic with the tfrontal, and usually also with the malar; the posterior connections being e, as in mammals, the more constant ones.

As the squamosal varies in form with the malar, so it likewise disappears ı it in ophidians; unless the anatomist, tracing it descensively, prefers to it again in the peculiarly developed hypotympanic of the anourans. Ac-ding to this view of the sudden resumption of its mammalian function in ard to the lower jaw in batrachia, the name 'squamosal' may be trans-ed to the hypotympanic in fishes; and, if we must view the pedicle *a*—*d*, fig. 5) as 'homologically compound,' and not, like the mandibular us, 'teleologically compound,' 28*d* seems to me a less arbitrary selection n the pieces of that long and subdivided pedicle, for the representative

* Ueber die Bedeutung der Schädelknochen, 4to, 1807, p. 12.

† Anatome Testudinis Europææ, fol. Parergon, 1821, p. 178, fig. 196, *i*.

‡ The tympanic bone 28 is described in the same work as 'squamosum sive quadratum,' 196, *g*.): the mastoid is rightly named.

§ Ossemens Fossiles, 4to. t. v. pt. ii. p. 85.

of the squamosal, than the proximal or uppermost piece (28a) to which vier has applied that name. If, indeed, Bojanus could have determine his own satisfaction or that of other anatomists, that the pedicle (28, fig. ' articulated by one end to the mastoid, and by the other to the mandible birds, was the 'squamosum,' then there would have been some ground regarding the bone (28a, fig. 5) connected in fishes, with the mastoid as 'squamosum.'

But when Cuvier had persuaded himself that the bone no. 8, fig. 23 birds, to which the tympanic pedicle is articulated, was the 'écaille du t poral,' we feel at a loss to know on what principles special homologies be traced, when we find the name transferred to the upper part of the t panic pedicle in fishes (fig. 5 28 a), which is articulated to the bone (8) equivocally answering to Cuvier's 'écaille du temporal' in birds. M. Aga is more consistent, and abandons with reason the Cuvierian determinatio the squamosal in fishes: if, however, the grounds assigned are conclusiv to the homology of no. 8, figs. 8 & 23 in birds with the mastoid of mamm and reptiles, M. Agassiz cannot be correct in regarding the bone no. 8, 5 in the fish, as the 'écaille du temporal.'

With reference to the idea entertained by Spix, Geoffroy and Agassiz the homology of the suborbital muciferous scale-bones in fishes (pl. 1, fig 73) with the malar bones of higher vertebrates, I may refer to what already been said in regard to the actual repetition of the osseous arch c necting the prefrontal with the postfrontal in certain birds (*ib.* fig. 1, where that arch coexists with, and independently of, the bone (*ib.* 26) rec nised as the 'malar' by both Spix and Geoffroy. The connection of malar, even in mammals, with the lacrymal and post-frontal is less const and characteristic of the bone than that with the maxillary and squamo And it may further be remarked, that the functional character of circu scribing a mucous duct, manifested by the lacrymal or anterior end of upper zygomatic or suborbital arch in the parrot, is superadded to the c racter of connections in proof that such arch, and not the true zygoma arch below, is homologous with the suborbital chain of bones in fishes. these discrepancies as to the jugal and squamosal in fishes arise, in my o nion, out of the circumstance that those bones are normally absent in th class; both 26 and 27, figs. 11, 22, 23, 24, 25, being accessory parts, develo only in saurians, chelonians, birds and mammals, for additional fixation of t upper jaw, or for additional expansion of the cranium, or for both purpose

According to this view, I regard the tympanic (28) as essentially chara terized in the oviparous vertebrates (fishes, reptiles, birds) by its free artic lation by a convex condyle with the mastoid above, and by a convex cond with the mandible below; and I regard its subdivisions in the lowest these vertebrates, in the same light as the subdivisions of the mandible its The formation of the tympanic cavity and support of the tympanic membra are secondary functions. The tympanic pedicle is essentially a single cran element, and actually so in all air-breathing vertebrates above batrachia We see plainly, even in the frog, that the portion which supports the 'me brana tympani' is a mere exogenous process of the pedicle: it has still less t appearance of a distinct part or process in the saurians, chelonians and bird and when the tympanic is excluded by the squamosal in mammals from normal office of supporting the mandible, it still manifests its character

* The inconstant ossicle suspended to the back part of the free extremity of the maxilla in the percoid fishes would have the best claim to homology with the malar, if the furth subdivision of the maxillary in the herring and lepidosteus did not indicate it to be a veg tative dismemberment of that bone.

ity, whether it be expanded into a 'bulla ossea,' extended into a long tube meatus, or both, as in fig. 24, 28, or whether, as in fig. 25, it be reduced to mere ring or hoop supporting the tympanic membrane, until it coalesces th other parts of the temporal, to form the tympanic or 'external auditory ocess' of that bone. In no air-breathing vertebrate have I ever found, or n described, the separation of the part of the tympanic forming the wall the tympanic chamber from the part supporting the tympanic membrane, this distinct, save in batrachia, from the part supporting the lower jaw*. e tympanic pedicle is still further subdivided in fishes; but M. Agassiz's ginal idea of the 'epitympanic' as a dismemberment of the pedicle, which proposed to call '*os carré supérieur*,' is, in my opinion, much more consist- with nature than his later determination of that bone as the 'mastoid,' than Cuvier's attempts to find the homologues of both the mammalian quamosal' and 'jugal' in the piscine subdivisions of the same pedicle. ere is as little ground for making the zygomatic process a distinct element m the squamous portion, as for severing the annular process from the rest the tympanic. This idea of the zygomatic as an independent piece, which . Köstlin has also adopted, seems to rest only on the mal-determination Bojanus and Oken of the true squamosal in birds and reptiles as the gomaticum' or 'jugale posterius': and the idea was perhaps further engthened in the mind of M. Agassiz, by what he deems to be the essen- l and characteristic function of the squamosal. But its protective cere- l or cranial scale is a peculiarly mammalian development; much reduced the ruminants and cetacea, and totally disappearing in the oviparous ver- rates. The zygomatic functions and connections are, notwithstanding a exceptions, as in the scaly *manis* and a few lizards, the essential homo- ical characters of the 'squamosal.' The necessity for forming an opinion the essential nature and general homologies of the parts blended together he human 'os temporis' by the ascensive or synthetic method, is strikingly mplified by the results of the application of M. Agassiz's idea of its nature his determination of the bones in the head of fishes.

As the palato-maxillary arch in most air-breathing vertebrates supports, ac- ding to my views, certain appendages, *e. g.* the malar and squamosal, which not present in fishes; so, I believe, with Cuvier, that the tympano-man- ular arch supports in fishes, certain appendages, which are not developed any other class. It is this fact, chiefly, that has led to so much discrepancy the attempts to determine by reference to bones in higher vertebrates the rcular bones of fishes,—the chief battle-field of homological controversy. the four opercular bones forming the diverging appendage of the tym- no-mandibular arch (fig. 5, 34 to 37) were deemed by Cuvier to be peculiar thyic super-additions to the ordinary vertebrate skeleton; whilst by Spix, offroy, and De Blainville they are held to be modifications of parts which

M. Agassiz applies the subjoined analysis of the 'temporal bone' to elucidate the homo- es of the skull of fishes:—"Nous distinguons encore dans le *temporal complet* les parties antes: l'*écaille*, servant de complément à la paroi latérale du crâne dans sa partie posté- ure; le *mastoïdien*, servant de rempart postérieur à la cavité tympanal; *la caisse*, logeant parties principales de la cavité tympanale; *l'anneau tympanique*, servant d'appui à la nbrane du tympan; l'*apophyse jugal*, formant l'appui postérieur de l'arcade zygomatique; *ophyse styloïde*, offrant une insertion à l'os hyoïde, par laquelle ce dernier se fixe au crâne; nfin l'*os carré*, formant la surface articulaire sur laquelle la mâchoire inférieure exerce mouvemens. La manière variée dont ces différentes pièces se soudent ensemble, se séparent e combinent, occasionnent ces innombrables variations auxquelles le temporal est sujet s son ensemble. L'*écaille du temporal* est destinée, comme nous venons de le voir, à pro- er les parties cérébrales postérieures de la tête, sur la face latérale du crane."—Recherches les Poissons Fossiles, t. ii. pt. 2, 1843, p. 62.

exist in the ordinary or endo-skeleton of other vertebrata. The lea Professor of Comparative Anatomy in King's College, London, who reg this as "the more philosophical mode of considering them*," has br stated the homologies proposed by the supporters of this view, viz. that opercular bones are gigantic representatives of the ossicles of the ear (S Geoffroy, Dr. Grant†): or that they are dismemberments of the lower (De Blainville, Bojanus),—a view refuted by the discovery of the com cated structure of the lower jaw in certain fishes, which likewise possess opercular bones: he then cites a third view, viz. that they are parts of dermal skeleton; "in short, scales modified in subserviency to the breatl function;" an opinion which Professor Jones frankly states that he der from my Lectures on Comparative Anatomy, delivered at St. Bartholom Hospital in 1835, and which he adopts, although its accordance with his proposition is not very clear. I have subsequently seen reason to modify view, though it has received the sanction of the greatest ichthyologist of present day, M. Agassiz; and, as I have since found, had presented itsel early as 1826, under a peculiar aspect to the philosophical mind of Profe Von Baer. In his admirable paper on the endo- and exo-skeleton, M. Von B expresses his opinion, that the opercular bones are (dermal) ribs or lat portions of the external cincture of the head‡. The idea of the relation of the opercular flaps to locomotive organs is presented by Carus, under fanciful view of their homology with the wing-covers of beetles and the val of a bivalve shell§. In 1836, M. Agassiz propounded his idea of the relat of the opercular bones to scales in a very precise and definite mann though, as I have elsewhere shown ||, the chief ground of his opinion is er neous. He says, "Les pièces operculaires des poissons ne croissent comme les os des vertèbres en général, par irradiation d'un ou de plusie points d'ossification; ce sont, au contraire, des véritables écailles, form comme celles qui recouvrent le tronc, de lames déposées successivem les unes sous les autres, et dont les bords sont souvent même dent comme ceux des écailles du corps. Tels sont l'opercule, le sub-opercule,

* Professor Rymer Jones, General Outline of the Animal Kingdom, 8vo, 1841, p. 509

† Lectures, Lancet, Jan. 11, 1834, p. 573; Outlines of Comp. Anat. p. 64.

‡ "In mancher Beziehung gehören die Kiemendeckel zu ihr, und ich halte sie um mehr für (Haut) Rippen, d. h. für Seitentheile der äussern Ringe des Kopfes, da ich sie a in den gewohnlichen Knockenfischen für nichts anderes ansehen kann. Hat bei diesen a der oberste Knochen des Kiemendeckels wenig Aehnlichkeit mit Rippen, so geht dage der unterste so unverkennbar in die strahlender Kiemenhaut über, das der Uebergang nicht zu verkennen ist."—Meckel's Archiv, 1826, 3 heft, p. 369.

An analogous idea of the relation of the opercular bones to the inferior or costal arches proposed by Geoffroy St. Hilaire (see Annales des Sciences, t. iii. pl. 9, and Cuvier, Hist. Poissons, i. p. 232), and has been adopted by the learned Professor of Comparative A tomy in University College, who, speaking of the occipital vertebræ, says, "The two exter and the two lateral occipitals form the upper arch, and the two opercular and two s opercular bones constitute the lower arch." (Lectures, Lancet, 1834, p. 543.) He sub quently, however, adopts and illustrates (p. 573) the homology of the opercular bones w the 'ossicula auditûs' of mammalia; and in the 'Outlines of Comp. Anat.' cites only t Spixian and Blainvillian hypotheses (pp. 64, 65). In my Hunterian Lectures (vol. ii. 18 pp. 113, 130), I have adduced the grounds which have led me to the conclusion that t opercular bones are neither ribs of the exo-skeleton, nor inferior arches of the endo-skelet but persistent radiating appendages of an inferior (hæmal) arch; not, however, of the occipi vertebra, but of the frontal; just as the branchiostegal rays are the appendages of the hæn arch of the parietal, and the pectoral fins of that of the occipital vertebræ. That parts both endo- and exo-skeleton may combine to constitute the opercular fin is the more pr bable, inasmuch as we see the same combination of cartilaginous and dermal rays in t pectoral fins of the plagiostomes, and in the median fins of most fishes.

§ Urtheilen des Knochen und Schalengerüstes, fol. p. 122.

|| Lectures on Vertebrata, p. 139.

ter-opercule. Le supra-scapulaire même peut être envisagé comme la mière écaille de la ligne latérale, dont le bord est également dentelé. On rrait dire aussi que le scapulaire n'est qu'une très grande écaille de la tie antérieure des flancs*." And he adds, "L'opinion que j'ai émise à r égard prouve que je suis loin d'admettre les rapports que l'on a cru iver entre les pièces operculaires et les osselets de l'oreille interne†."

apprehend that the idea of the development of the opercular bones by successive excretion or deposition of layers, one beneath the other, acding to the mode in which M. Agassiz supposes scales to be formed, was ived merely from the appearance of the concentric lines on the opercular, opercular, and interopercular bones in many fishes. I have examined development of the opercular bone in young gold-fish and carp, and I that it is effected in precisely the same manner as that of the frontal and etal bones. The cells which regulate the intussusception and deposition he earthy particles make their appearance in the primitive blastema in cessive concentric layers, according to the same law which presides over concentric arrangements of the radiated cells around the medullary canals he bones of the higher vertebrata: and the term 'successive deposition,' he sense of excretion, is inapplicable to the formation of the opercular es. The argument in favour of their dermal character drawn from the nomena of the development of the opercular flap, would equally apply to e the bones (ulna, radius, carpus, &c.) supporting the pectoral fin, to be rmal' bones‡.

he interopercular as well as the preopercular bones exist in the *Lepiren annectens* with all the characters, even to the green colour, of the rest e ossified parts of the endo-skeleton; the preopercular, as an appendage e tympanic arch, retaining its primitive embryonal subcylindrical form, interopercular being partly attached to the hyoid arch. Of the suprapular there is no trace in the lepidosiren; but in the sturgeon it plainly ts as part of the cartilaginous endo-skeleton, under the same bifurcate , and double connection with the cartilaginous skull, which it presents ost osseous fishes. The large triangular bony dermal scale firmly adheres s broad, triangular, flat, outer surface. The epi- and meso-tympanic ilages in like manner expand posteriorly, and give a similar support to large opercular ganoid scale. Were the supporting cartilages of the cular and suprascapular scales to become ossified in the sturgeon, they nt become anchylosed to the dermal bony plates, and bones, truly homous with the opercular and suprascapular in ordinary osseous fishes, ld thus be composed of parts of the endo- and exo-skeleton blended ther. I cannot, therefore, concur with Von Baer in the opinion that the cular bones are ribs of the exo-skeleton, nor with Agassiz that both the cular and suprascapular bones are merely modified scales. In explaining views of the opercular bones, I am compelled, believing them to have no ial homologues in higher animals, to express those views in the terms of gher generalization. The suprascapular bone (fig. 5, 40) is the upper or part of the hæmal arch of the occipital segment of the skull, and corres in serial homology with the epi-tympanic portion (28 *a*) of the mandir arch, and with the palatine portion (20) of the maxillary arch. The cular bones are the diverging appendages of the tympano-mandibular

Recherches sur les Poissons Fossiles, livraison 6me, 1836, tom. iv. p. 69.
Ib. p. 73.
'L'embryologie nous prouve, en effet, que la formation de l'appareil operculaire n'est simple produit de la peau, qui peu-à-peu s'étend par dessus les branchies, d'abord rement dégagées dans l'embryon."—*Ib.* p. 61.

arch, and correspond, in serial homology, with the branchiostegal append of the hyoid and the pectoral appendages of the scapular arches, and the same title to be regarded as cephalic fins, and as parts of the no system of the vertebrate endo-skeleton; but neither opercular bones branchiostegal rays are retained in the skeletons of higher vertebrata. diverging appendages of vertebral segments make their first appearan the vertebrate series as 'rays'; and the opercular bones are actually re sented by cartilaginous rays, retaining their primitive form in the pla stomes. In the conger the subopercular still presents the form of a long, slender fin-ray.

The opercular and subopercular, in ordinary osseous fishes, may freque coalesce, like the suprascapular, with their representative scales of the der system; but they are essentially something more than peculiarly develo representatives of those scales. M. Agassiz, indeed, excepts the preo cular bone from the category of "pièces cutanées," believing it to be homologue of the styloid process of the temporal bone in anthropotomy the 'stylo-hyal' of vertebrate anatomy, as the piece, viz. which completes hyoid arch above. "C'est en effet," he says, "cet os à la face interne du l'os hyoide des poissons est suspendu, qui s'articule en haut avec le mas dien et très souvent même sur l'écaille du temporal." So far as my ob vation has gone, it is a rare exception to find the hyoid arch suspende the preoperculum; the rule in osseous fishes is to find the upper stylif piece of the hyoid arch (fig. 5, 38) attached to the epi-tympanic (28 *a*) c to its junction with the meso-tympanic bone (28 *b*). It is equally the rul find the preopercular (34) articulated with the epi-, meso-, and hypo-t panics; and it is an exception, when it rises so high as to be connected w the mastoid ('écaille du temporal' of Agassiz). If the stylo-hyal be not upper piece of the hyoid arch displaced, and if the upper piece connect that arch with the mastoid is to be sought for in osseous fishes, I sho rather view it in the posterior half of the epi-tympanic (28 *a*), which is usu bifurcate below and very commonly also above, when the posterior up division articulates with the mastoid, and one of the lower divisions with hyoid arch.

The normal position, form, and connections of the preoperculum clea bespeak it to be the first or proximal segment of the radiated appendage the tympano-mandibular arch: the opercular, subopercular, and interop cular bones form the distal segment of the same appendage.

M. Vogt, in supporting M. Agassiz's views of the Ganoid order, reitera his original idea that the preopercular bone is the proximal piece (stylo of an arch distinct from the tympano-mandibular one; but as the chief grou of this opinion rests on a simple question of fact easily determinable, v whether, as a rule, the hyoid arch is suspended from the preoperculum, a this from the mastoid in fishes, neither of which accord with my observati of their connections of those parts, the verdict may be left to the experien of other observers. From a remark of M. Vogt's*, viz. that "M. Mül attache, à ce qu'il parait, trop peu d'importance *à ce fait*, que toujours préopercule, et cela aussi chez les Siluroïdes, sert de point d'attache à l'a hyoïdien," it would seem that, perhaps, the accomplished physiologist a ichthyologist of Berlin had not found *the fact*; and, therefore, gave not mo than its due importance to the rare exceptional circumstance of such an a tachment. The preopercular can be removed in most fishes, except whe as in the siluroids, it coalesces with the tympanic arch, without dislocati

* Annales des Sciences, 1845, p. 56.

listurbing the connections of the true stylo-hyal (fig. 5, 38) with the epiipanic (28 *a*) from which it is normally suspended.

M. Vogt correctly observes that the 'temporal' (epitympanic, 28 *a*), 'symctique' (mesotympanic, 28 *b*), and 'jugulaire' (hypotympanic, 28 *d*), "à seuls forment déjà un arc suspensoir complet, à la face postérieure quel le préopercule est seulement accolé*." But this only proves that the operculum is an appendage to such arch, not that it is a suspensory pier i second arch.

The only essential modification which the siluroids present is the confluence he preoperculum with the true tympanic pedicle, here reduced to a single :e. But this does not disprove its character as an appendage of the pano-mandibular arch, any more than does the confluence of the ulna and .us with the scapular arch in the sturgeon disprove the character of those nents as appendages of that arch. I have not been able to trace in the roids the primitive boundaries of the coalesced preoperculum to such an ent as to justify the statement, that it is intercalated between the epitymic and hypotympanic, replacing the mesotympanic: but, if the preopercular uld extend in any siluroid fish so far as M. Vogt describes, this excepal development would rather prove it to belong essentially to the tymic and not to the hyoidean arch: at least it is only through this abnorencroachment that the preopercular can detach the stylohyal from the ympanic.

As the otosteals, or 'ossicula auditûs,' have borne a prominent share in the ussions of the special homologies of the tympanic pedicle and its appends, I may here remark that the extension in the embryo mammal of the g and slender process of the malleus in the direction of the mandible, and ontinuation or connection with the cylindrical cartilage (hæmal portion he tympano-mandibular arch) from which the lower jaw is subsequently loped, is a circumstance which renders the idea of the malleus, at least, g a modified element of the tympano-mandibular arch in batrachians fishes, worthy of consideration. The prolongation from the mesotymc of the cylindrical cartilage, described by Meckel, and around which mandible is ossified in fishes, and the characteristic cylindrical or styloid n of the mesotympanic, have induced M. Vogt† to view that bone, the nplectique' of Cuvier, as the homologue of at least part of the malleus; at the same time of the bone called 'tympano-malléal' by Dugés (my sotympanic') in the batrachians. M. Vogt offers no other reasons for determination. I find that the cartilage which in the batrachians forms medium of communication between the semi-ellipsoid ossicle (stapes) ng the fenestra ovalis and the tympanic membrane, is repeated or reproed in the more malleiform cartilage connecting the columelliform stapes e saurian reptiles to the membrana tympani. In birds a portion of the lage attached to the tympanum becomes ossified and coalesces with the melliform stapes; and at the angle of union one or two cartilaginous esses exist, which some anatomists have compared with the incus. But natomists have concurred in recognising the homology of the peripheral -down portion of the long columella, which adheres to the membrana pani, with the part of the malleus called 'manubrium,' or handle, in malia. The superadded modifications characteristic of the otosteals in class, have their seat between the manubrium mallei and the stapes, and fly result in the development of the new bone called 'incus' and its epiis, which has been termed the 'os orbiculare.' Notwithstanding, therethe connection of the 'processus gracilis mallei' with the embryonic

* Annales des Sciences, 1845, p. 55.

† *Loc. cit.* p. 58.

hæmal or visceral cartilage of the mandibular arch in mammals, the h logy of the malleus is so clearly traceable down to its first independent nifestation in coexistence with the tympanic membrane of the batrachi which it connects the unequivocally acoustic ossicle representing the 'sta that the reference of all the additional ossicular mechanism of the ear-c to the same system of the skeleton as the petrosal itself, appears to me t most consonant with the recognised facts in their development and comp tive anatomy.

M. Agassiz has never countenanced the idea of the reproduction of mammalian tympanic ossicles in a magnified form in either the tymp arch or its opercular appendages. Returning to the consideration of t bones in the last volume (p. 68) of his admirable 'Recherches,' he reaff his opinion, that the opercular, subopercular, and interopercular are 'c lets particuliers de la peau;' but calls them 'branchiostegal rays.' If had meant that they were parts essentially distinct, but comparable to true branchiostegals, he would have accurately enunciated their 'serial mology.' M. Agassiz, however, expressly repudiates this idea of repre tative relation, and affirms them to be part of one and the same seric rays. "Mais en disant que les pièces operculaires sont des rayons branc stègues, je n'entends point faire une simple comparaison, mais bien affirr que je considère ces plaques osseuses simplement comme les rayons br chiostègues supérieurs*." This idea is, in fact, a necessary consequenc M. Vogt's conclusion, that the preoperculum is the upper or styloid elem of the hyoidean arch. The combination of the opercular rays or bones w the branchiostegals in the support and movements of the continuous g cover and gill-membrane, does not prove them to be diverging appenda of the same arch, any more than the similar combination of the rays of pectoral and ventral fins in the sucker of the *Cyclopterus* proves those r to be parts of the same arch. And I may repeat that, admitting the hume to be, as Bakker surmised, confluent in all fishes with the bone 52, fig. and since in the plagiostomes, sturgeons and lophioids, the second segment the rudimental fore-limb is not liberated from the supporting arch; so, li wise, the proximal member of the opercular limb may remain, or become some instances confluent with its sustaining arch, without that exceptio state invalidating the determination deduced from its more constant and gular character as the proximal element of the free appendage to that arc

Hyoid Bones.—The third inverted arch of the skull is suspended in fisl by a slender styliform bone, the 'stylohyal' (fig. 5, 38), from the lower end the epitympanic (28 *a*) close to the joint of the styliform 'mesotympan (28 *b*); and it is connected, through the medium of the posterior division a joint of the epitympanic, with the mastoid (8). Now, either that divisi of the epitympanic may be viewed, by virtue of its proper articular condy above, and its connection with a distinct inverted arch below, as the proxim piece of that arch, coalesced with the proximal piece of the next arch advance, which articulates with the post-frontal; or, it may be viewed as a excessive development of the proximal piece of the tympano-mandibular arc which, extending backwards, has displaced the hyoid from the mastoid, ju as the squamosal, by a similar backward development, in mammals, displac the mandibular arch from the tympanic.

According to the first view, the bone no. 38 would be a dismembermen of the proximal element of the hyoid arch; according to the second view, i would be the entire element reduced and displaced: in both cases it woul be homologous with the proximal slender piece of the hyoid arch in al

* Recherches sur les Poissons Fossiles, v. pt. ii. p. 68.

ebrata, and to which piece the term 'styloid' or 'stiliform' has been ·n from the fish up to man (see TABLE I.). The homology, indeed, is so ious, that M. Agassiz, in accepting the conclusion of M. Vogt, that the e (fig. 5, 34), peculiar to osseous fishes, which so rarely articulates di-ly with the mastoid or with the hyoid arch, and so constantly sustains distal segment of the operculum, was the homologue of the 'processus formis ossis temporis,' nevertheless retains the name 'styloïde' for the no. 38 in question.

'he true homology of no. 34, already explained, removes the anomaly of ·ing that peculiarly piscine bone as the homologue of a constant element he hyoid arch in all the vertebrate classes, and the greater anomaly of introduction of a new element—a styloid piece of the os hyoïdes—in tion to the 'styloid process of the temporal' in fishes. The 'stylohyal' :ulates below to the apex of a triangular piece (39), which is pretty con-·t in fishes, and to which I give the name of 'epihyal,' as being the upper ·ie two principal parts of the cornu or arch: the third longer and stronger e is the 'ceratohyal' (*ib.* 40).

'he keystone or body of the inverted hyoid arch is formed by two small :ubical bones on each side, the 'basihyals' (*ib.* 41). These complete the ·y arch in some fishes: in most others there is a median styliform ossicle, nded forwards from the basi-hyal symphysis into the substance of the ;ue, called the 'glossohyal' (*ib.* 42), or 'os linguale'; and another symme-al, but usually triangular, flattened bone, which expands vertically as it nds backwards, in the middle line, from the basihyals; this is the 'urohyal' 43). It is connected with the symphysis of the coracoids, which closes below ·fourth of the cranial inverted arches, and it thus forms the isthmus which arates below the two branchial apertures. In the conger the hyoidean ı is simplified by the persistent ligamentous state of the stylohyal, and :he confluence of the basi-hyals with the ceratohyals: a long glossohyal rticulated to the upper part of the ligamentous symphysis, and a long pressed urohyal to the under part of the same junction of the hyoid arch. : glossohyal is wanting in the *Murænophis*.

'he appendages of the hyoidean arch in fishes retain the form of simple, ıgated, slender, slightly curved rays, articulated to depressions in the outer ı posterior margins of the epi- and cerato-hyals: they are called "bran-ostegals," or gill-cover rays, because they support the membrane which es externally the branchial chamber. The number of these rays varies, their presence is not constant even in the bony fishes: there are but :e broad and flat rays in the carp; whilst the clupeoid *Elops* has more ı thirty rays in each gill-cover: the most common number is seven, as he cod (fig. 30, 44). They are of enormous length in the angler, and ·e to support the membrane which is developed to form a great receptacle each side of the head of that singular fish.

n the class of fishes, certain bony arches, which appertain to the system the visceral skeleton, succeed the hyoidean arch, with the keystone of ch they are more or less closely connected. Six of these arches are pri-·ily developed, and five usually retained; the first four of these support gills, the fifth is beset with teeth and guards the opening of the gullet: latter is termed the 'pharyngeal arch,' the rest the 'branchial arches.'

The lower extremities of these arches adhere to the sides of a median chain ossicles, which is continued from the posterior angle of the basihyal, or m above the urohyal, when this is ossified: the bones which form those remities are the 'hypobranchials'; and they support longer bent pieces, ed 'ceratobranchials.' It is with these elements of the branchial arches in fishes and perennibranchiate batrachians that we are chiefly con in tracing the homology of the hyoid apparatus in the air-breathing brates. With regard to the branchial and pharyngeal arches, which their full development only in the class of fishes, I regard them as appe ing to the system of the splanchno-skeleton, or to that category of bo which the heart-bone of the ruminants and the hard jaw-like pieces su ing the teeth of the stomach of the lobster belong. The branchial a are sometimes cartilaginous when the true endoskeleton is ossified: th never ossified in the perennibranchiate batrachians, and are the first t appear in the larvæ of the caducibranchiate species; and both their and mode of attachment to the skull demonstrate that they have no ess homological relation to its endoskeletal segments.

The hyoid arch or apparatus retains most resemblance to that of fis the *Siren lacertina*; the basihyal is simplified into a single osseous s late piece, with the bowl of the spoon anterior, and supporting a broad flat semicircular glossohyal. A strong and thick ceratohyal is articu by means of a small cartilage to the side of the expanded part of the hyal, and a cartilaginous epihyal arches backwards from its upper end cartilaginous urohyal extends from the hind end of the basihyal, an pands into a radiated disc, which supports the membranous trachea an simple glottis. One pair of bony 'hypobranchials' is articulated to basi-uro-hyal joint and a second pair to the sides of the urohyal: and to upper and outer ends of these are attached four pairs of cartilaginous 'ce branchials.' The fimbriated branchiæ are attached to the three ant ceratobranchials.

In the proteus the urohyal is absent, and it is not again developed in batrachian. The long subcylindrical basihyal supports a subcircular c laginous discoid glossohyal, and at the angle of union the bony ceratoh are sent off. A pair of hypobranchials diverge from the end of the basih to which a second small pair of basibranchials are loosely connected b aponeurosis. These support three ceratobranchials on each side, which bony.

In the newts there is neither a glossohyal nor urohyal, or but a rudin of the latter, to each side of which are articulated two hypobranchials, w distal ends converge on each side to support a single cartilaginous gill- rudiment of a ceratobranchial. The special homologies of all those part the complex hyoid, rendered more complex by the retention of part of branchial skeleton, are clearly demonstrated by pursuing the metamorph of the hyo-branchial skeleton in the larvæ of the anourous batrachians. the full-gilled tadpole a short and simple basihyal supports laterally t thick and strong ceratohyals, and posteriorly two short and broad hy branchials, to which four ceratobranchials are attached: all the parts cartilaginous. The type of this stage is retained in the siren, with the his logical progress to bone in the hyoid and hypobranchial pieces. The seco well-marked stage in the tadpole shows an extension of the external a posterior angles of the hypobranchials, with progressive absorption of t cartilaginous ceratobranchials. The growth and divergence of the poster angles of the hypobranchials refer to the development of the larynx, n commencing, which part they are destined to support. That period may described as the third stage at which the ceratobranchials have disappeare and the posterior angles of the hypobranchials increase in length and assun the character of posterior cornua of the os hyoides. The last and adu stage shows the ossification of the elongated angles of the hypobranchial the coalescence of their cartilaginous bases with the basihyal, the expansi he basihyal and extension of its anterior and external angles; in front of ch the now long and slender ceratohyals usually coalesce with the basi-l; their opposite ends having shifted their attachments and retrograded, other hæmal arches of the skull, in the course of the metamorphosis. he case of the hyoid arch of the frog, the change of place is from the panic pedicle backwards to the persistent cartilaginous petrosal: and is a very suggestive and significant change. All the parts of the hyoid ain cartilaginous except the appended and persistent detachments from visceral system of the branchial arches: these long 'hypobranchials' ornes thyroïdiennes' of Cuvier and Dugés) diverge and include the larynx heir fork. The relative position, connexions and office in subserviency he larynx, to which the retained parts of the splanchno-branchial arches introduced in the lowest of the air-breathing vertebrates, are preserved in the higher classes. The 'hypobranchials' are as constant in their ex-ice, therefore, as the upper larynx itself, and attach themselves more cially to the thyroid element of that larynx. We recognise them by this tion in birds and man (46, figs. 23 and 25), where they always much ex-l the parts of the true hyoid arch (cerato- and epi-hyals) in length; and irds, where these elements (40, fig. 23) are sometimes obsolete and always mental, the hypobranchials have been mistaken by both Cuvier and ffroy* for the ceratohyals or anterior cornua.

or the modifications and special homologies of the complex hyoid appa-s in lizards, I refer to my 'Lectures on the Vertebrata.' The crocodiles r a well-marked ordinal difference from those inferior sauria in this as ost other parts of their structure. The basihyal and thyrohyals have esced to form a broad cartilaginous plate, the anterior border rising like a e to close the fauces, and the posterior angles extending beyond and sus-ing the thyroid and other parts of the larynx. A long bony 'ceratohyal' . 22, 40), and a commonly cartilaginous 'epihyal' (*ib.* 39), are suspended ı ligamentous 'stylohyal' to the paroccipital process; the whole arch ng, like the mandibular one, retrograded from the connection it presents shes.

ı birds as in chelonians, the ceratohyals are much reduced, and the chief nua' of the hyoid are represented by the hypo- and epi-branchials (thy-als), which here attain their maximum of length and tenuity. The basi-l (fig. 23, 41), as in *Chelys*, is long and slender, but is always a simple e; and, as in lizards, is usually most expanded posteriorly, from which ansion the thyrohyals (46) are sent off. Conforming with the long and der tongue in most birds, the basihyal extends forwards, and is articu-d with the rudimental ceratohyals (40), when these exist, at some distance n the thyrohyals. A commonly long and slender, sometimes spatulate sohyal (42), is articulated to the fore-part of the basihyal; and a con-tly long, slender and pointed urohyal (43) is articulated with the posterior of the basihyal, and extends backwards beneath the trachea. The thyro-ls (46) diverge and include the larynx in their fork; and support at their emities a bony or gristly (ceratobranchial) style (47). This is never ched by ligament to the base of the skull, but is suspended freely, as in chelonia, by the glossohyoid and omohyoid muscles; it, however, curves r the back and upper part of the cranium in the woodpeckers, and the emities of both cerato-branchials are inserted, by way of rare exception hat bird, into the right nostril.

n mammals the normal completion of the hyoidean arch, as it first ap-

* Dugés appears to have first pointed out this error, but without, however, perceiving the homology of his 'cornes thyroïdiennes' with the hypobranchials of fishes.

pears in fishes, is again resumed, and that not by a slender cartilag the frog, but by a chain of bones, in which we again recognise the (fig. 24, 40), epi- (39) and stylo- (38) hyals suspending the basihyal (4 the tongue to the base of the skull, often to the petrosal, sometimes tympanic, or to the mastoid, or to the exoccipital. The ungulates a true carnivora best display this type.

In man (fig. 25) the ceratohyals are reduced, as in birds, to mere cles of bone (40), and the extent of the arch between them and the hyals, which become anchylosed to the temporal bones, retains its pri ligamentous condition. Occasionally, however, ossification extends the stylohyoid ligament, and marks out, as in the specimen figur Geoffroy St. Hilaire (Philosophie Anatomique, pl. 4, fig. 87), the mor mal proportions of the ceratohyal, and also the epihyal. Other exam this 'monstrosity' are recorded in works on anthropotomy. The hyal (46)—the last remnant of the branchial arches—maintains more stancy in its existence and proportions; but manifests its true charac free suspension below the skull, and an articulation by short ligaments angles or horns of the thyroid cartilage.

The remarks already made on the special homologies of the parts o scapular arch and its appendages, preclude the necessity of further exte the present chapter of this work.

Chapter II.—General Homology.

Historical Introduction.

On taking a retrospect of the results of the researches of anatomists the special homologies of the cranial bones, the student of the science, little soever practised in such inquiries, cannot but be struck with the am of concordance in those results. It must surely appear a most remark circumstance to one acquainted only with the osteology of the human fr that so many bones should be, by the common consent of comparative tomists, determinable in the skull of every animal down to the lowest oss fish. This fact alone, so significant of the unity of plan pervading the tebrate structure, has afforded me, at least, a large ground of hope much encouragement to perseverance in the reconsideration of those p on which a difference of opinion has prevailed; and in the re-investigatio what is truly constant and essential in characters determinative of spe homologies.

In this, as in every other inquiry into nature, the first labours are ne sarily more or less tentative and approximative: but if errors have to eliminated in the course of successive applications of fresh minds to task, truths become confirmed and established. And I regard the bod such truths (see Table I.) to be now so great, in respect of the determina of the homologous bones in the heads of all vertebrate animals, as to im ratively press upon the thinking mind the consideration of the more gen condition upon which the existence of relations of special homology depe

Upon this point the anatomical world is at present divided, lacking required demonstration. The majority of existing authors on comparat anatomy have tacitly abandoned*, or with Cuvier and M. Agassiz, h

* Wagner, 'Lehrbuch der Zootomie,' 8vo, 1843, 1844. Siebold and Stannius, 'Le buch der Vergleichende Anatomie,' 8vo, 1845, 1846. Milne-Edwards, 'Elemens Zoologie,' 8vo, 1834. Prof. Rymer Jones, 'Outline of the Animal Kingdom and Man of Comparative Anatomy,' 8vo. 1841. The sentiments which this pleasing and instruct writer expresses, are probably akin to those which have influenced the above-cited auth

tly opposed the idea of 'special homology' being included in a higher .f uniformity of type.

:t the attempt to explain, by the Cuvierian principles, the facts of special ›logy on the hypothesis of the subserviency of the parts so determined nilar ends in different animals,—to say that the same or answerable bones r in them because they have to perform similar functions—involve many ulties, and are opposed by numerous phænomena. We may admit that nultiplied points of ossification in the skull of the human fœtus facilitate, were designed to facilitate, childbirth; yet something more than such a purpose lies beneath the fact, that most of those osseous centres repre- permanently distinct bones in the cold-blooded vertebrates. The cra- of the bird, which is composed in the adult of a single bone, is ossified the same number of points as in the human embryo, without the pos- ty of a similar purpose being subserved thereby, in the extrication of hick from the fractured egg-shell. The composite structure is repeated e minute and prematurely-born embryo of the marsupial quadrupeds. eover, in the bird and marsupial, as in the human subject, the different s of ossification have the same relative position and plan of arrange- : as in the skull of the young crocodile, in which, as in most other rep- and in most fishes, the bones so commencing maintain throughout life primitive distinctness. These and a hundred such facts force upon the emplative anatomist the inadequacy of the teleological hypothesis to unt for the acknowledged concordances expressed in this work by the 'special homology.' If, therefore, the attempt to explain them as the ts of a similarity of the functions to be performed by such homolo- parts entirely fails to satisfy the conditions of the problem; and if, rtheless, we are, with Cuvier, to reject the idea of their being manifes- ns of some higher type of organic conformity on which it has pleased divine Architect to build up certain of his diversified living works, : then remains only the alternative that special homologies are matters nance.

his conclusion, I apprehend, will be entertained by no reasonable mind; reverting, therefore, to the more probable hypothesis of the dependence he special resemblances upon a more general law of conformity, we : next to inquire, what is the vertebrate archetype? The gifted and -thinking naturalist, OKEN, obtained the first clew to this discovery by

is subject. "It is not by any means our intention to engage our readers in discussing le conflicting and, sometimes, visionary opinions entertained by different authors re- to the exact homology of the individual bones forming this part of the skeleton; and hall, therefore, content ourselves by placing before them, divested as far as possible of fluous argumentation, Cuvier's masterly analysis of the labours of the principal inquiries erning this intricate part of anatomy."—p. 494. A later English author, who has em- d a most valuable amount of careful and exact osteological observation in the article logy" of the 'Encyclopædia Metropolitana' (4to, 1845), seems scarcely to regard even letermination of special homologies as a necessary object of anatomical research. Thus, cussing the differences of opinion respecting the coracoid (fig. 5, 48). he says, "Bakker's , however, if it be absolutely necessary to hunt up analogies, seems more correct."— 2.

his reserve is, however, perhaps less obstructive to the philosophical progress of anatomy to the requisite resumption of original inquiry to that end, than the mere reproduction le transcendental views of others without criticism or attempt to explain or refute the ctions to such views which have been promulgated by so great authorities as Cuvier and ssiz. Thus Bojanus's 4-vertebral theory of the cranial part of the skull is adopted by le Blainville (Ostéographie, 4to); whilst Dr. Grant (Outlines of Comparative Anatomy, 1835, p. 63) deems the composition of the skull, in fishes, to correspond nearly with froy's theory of this part of the skeleton being composed of seven vertebræ, each con- ng of a body with four elements above and four elements below.

the idea of the arrangement of the cranial bones of the skull into segm like the vertebræ of the trunk. He informs us that walking one day in Hartz forest, he stumbled upon the blanched skull of a deer, picked up partially dislocated bones, and contemplating them for a while, the tr flashed across his mind, and he exclaimed "It is a vertebral column!*" O afterwards tested and matured this happy inspiration by examining the sk of a cetacean, a chelonian, and a cod-fish in Dr. Albers's museum at Brem and on his return to Jena in 1807, he published his beautiful generalizatio a now very scarce Introductory Lecture, or "Programm beim Antritt der I fessur," entitled 'On the signification of the bones of the skull'†. He il trates his views by reference to the skull of a ruminant. "Take," he s "a young sheep's skull, separate from it the bones of the orbit, also th cranial bones which take no share in the formation of the 'basis cranii,' the frontal, parietal, ethmoid and temporal, and there will remain an osse column which any anatomist, at first glance, would recognise as three bo of a kind of vertebræ with transverse processes and foramina. Replace cranial bones with the exception of the temporals, for, without these, cavity is still closed, and you have a cranial vertebral column, which diff from the true one ('von der wahren') only by its more expanded neu canal (Ruckenmarkshöhle). As the brain is a more voluminously develop spinal chord, so is the brain-case a more voluminous spinal column. the cranium includes, then, three vertebral bodies, so must it have as ma vertebral arches. These are next to be sought out and determined. O sees the sphenoid divided into two vertebræ; through the foremost pass t optic nerves, through the hindmost the maxillary nerves (*par trigeminum* I call one the 'eye-vertebra' (Augwirbel), the other the 'jaw-verteb (Kieferwirbel). Upon this latter abuts the basilar process of the occipi bone and the petrous bones: both belong to one whole. As the optic ner perforates the 'eye-vertebra,' and the trigeminus the 'jaw-vertebra,' so t acoustic nerve takes possession of the hindmost vertebra. I call it, ther fore, 'ear-vertebra' (Ohrwirbel): and I regard this as the first cranial ve tebra; the jaw-vertebra as the second, and the eye-vertebra as the third." *ib.* p. 6.

After entering upon the difficulties which beset him in determining wheth the petrosal belonged to the first (Ohrwirbel) or the second (Kieferwirbe and enunciating his views on the essential relations of each cranial verteb with a single special sense (excluding, however, smell and taste, as bei inferior in dignity to the others), Oken proceeds, in his characteristic bo metaphorical language:—"Bones are the earthy hardened nervous system Nerves are the spiritual soft osseous system—Continens et contentum."

"Between the sphenoid and occipital, between the sphenoid and petros between the parietal (the temporal being removed) and the occipital, the runs a line which defines the anterior boundary of the first vertebra. In th line between the two sphenoids, or that which in man extends anterior

* "Im August 1806 machte ich eine Reise über den Hartz,"—"ich rutschte an der Sü seite durch den Wald herunter—und siehe da; es lag der schönste gebleichte Schädel ein Hirschkuh vor meinen Füssen. Aufgehoben, umgekehrt, angesehen, und es war geschehe *Es ist eine Wirbelsäule!* fuhr es mir wie ein Blitz durch Mark und Bein—und seit dies Zeit ist der Schädel eine Wirbelsäule."—Isis, 1818, p. 511.

† Uber die Bedeutung der Schädelknochen, 4to, 1807. I am indebted to my frien Mr. Tulk, the able translator of 'Wagner's Comparative Anatomy,' for the opportunity perusing this most suggestive and original essay, which does not exist in either the Libra of the British Museum, that of the College of Surgeons, or that of the Medico-Chirurgic Society. Mr. Tulk is at present engaged in the arduous task of translating the "Lehrbuc der Natur-philosophie" of Oken for the 'Ray Society.'

iterygoid processes laterally and upwards through the fissura orbitalis rior, anterior to the great ala, and finally between the frontal and the tal bones, we trace another line, which divides the second from the vertebra" (*ib.* p. 7).

"Now," says Oken, "take the ear-vertebra from a fœtus of any mammal man, place near it an immature dorsal vertebra, or the third cervical crocodile, and compare the pieces of which they consist, their form, their ents, and the outlets for the nerves.

According to Albinus and all anthropotomists, each vertebra of the s consists of three distinct parts—the body and the two neurapophyses entheile). You have the same in the occipital bone, but more clearly more distinctly: the 'pars basilaris' is separated as the body of the ver- from the 'partes condyloideæ,' which form the lateral parts: these still more distinct from the 'pars occipitalis' which forms the spinous ess: even this part is often bifid, like the spinous processes in *spina a.*"

Since then the foramen magnum is the hinder or lower opening of a ebral canal, the condyles true oblique vertebral processes, the foramen rum an intervertebral foramen, and the crista occipitalis a spinous pro- proved to be such by both its position and the muscles inserted into it,— lastly the whole occipital bone in relation to its form as well as its tion—inclosing the cerebellum as a production of the spinal chord,—is ie and in every sense characteristic vertebra, it is unnecessary to dwell diffusely on parts, the bare mention of which suffices to make their re recognizable."—*ib.* p. 7.

his will serve as an example of the close observation of facts, the philo- ical appreciation of their relations and analogies, and, in a word, of the t in which Oken determines the vertebral relations of the cranial bones ie skull: and I refer to TABLE II. for his conclusions as to the parts of second and third cranial vertebræ.

everting to the petrosal, Oken thus beautifully and clearly enunciates essential nature and homology:—"You will say I have forgotten the s petrosa.' No! It seems not to belong to a vertebra, as such; but to 'sense-organ' (Sinnorgan), in which the vertebral- or ear-nerve loses f; and, therefore, is as distinct an organ from a vertebral element as is other viscus (Eingeweide), or as is the eyeball itself. The (cause of) sion (as to the homology of the petrosal) lies in this, viz. that it must be ied agreeably with its nature (wesen), just as the eye must be crystallized."

lthough Oken does not in this essay formally admit a fourth vertebra rior to the 'eye-vertebra,' he recognises the vertebral structure as being ied out rudimentally or evanescently, by the vomer, as the prolongation he cranio-vertebral bodies, by the lacrymal bones, as their neurapo- ses, and by the nasal bones, as the spinous process. His ideas of a ebra have evidently at this period not extended beyond the ordinary ropotomical one of centrum and neural arch with its transverse, oblique, spinous processes. When he indicates (beautifully and truly) the general iology of the palatine bones, as pleurapophyses, under the name of an- losed or immoveable ribs of the head, it has reference to the transcen- tal idea of the repetition in the head of all the parts of the body. Thus squamosal in mammals and the tympanic in birds represent the 'scapula' he head, and at the same time, also, the ilium. The homologue of the amosal (fig. 21, 27) in the bird is the 'humerus capitis': the malar (26) the maxillary (21) are the 'oberarm' (radius and ulna capitis): the pre- xillary (22) is the 'manus capitis.' The segments of the hind limb are represented by divisions of the compound lower jaw in the crocodile embryo bird (see TABLE, No. III.). The pterygoids (24), the essential stinction of which from the sphenoid Oken clearly recognises, are his 'c culæ capitis.' Oken hints at, without accepting, the (serial) homolog the hyoid arch with the pelvis; but he regards the stylohyal (38) as 'sacrum capitis' (*ib.* p. 16).

The year after the publication of Oken's famous 'Introductory Lectu Prof. Duméril, apparently unacquainted with its existence, communica to the French Institute a memoir entitled 'Considérations générales l'analogie qui existe entre tous les os et les muscles du trone dans les maux,' the second paragraph of which is headed "De la tête consid comme une vertèbre, de ses muscles et de ses mouvements." In this p graph, repeating the homological correspondences, demonstrated by Ol between the basioccipital as a vertebral centrum, the condyles as 'obli processes,' and the occipital protuberance as a spinous process, he adds, t the mastoid processes are entirely conformable to transverse processes. A M. Duméril has, I believe, here the merit of having first enunciated general homology of the mastoids, although he does not aim at showing which vertebral segment of the skull they properly belong. Nor, inde with the exception of an observation that "very often the body of the sp noid, like the 'apophyse basilaire' of the occiput, resembles the body (vertebra," does he push the transcendental comparisons further. Geoff St. Hilaire tells us*, that even the moderate and very obvious illustrati of the general homologies of the cranial bones, which M. Duméril dedu from the anatomy of the occiput, excited an unfavourable sensation in bosom of the 'Académie;' and that the phrase 'vertèbre pensante,' whic facetious member proposed as an equivalent for the word 'skull,' and wh circulated, not without some risibility, along the benches of the learn during the reading of the memoir, reaching the ears of the ingenious auth the dread of ridicule checked his further progress in the path to the higl generalizations of his science, and even induced him to modify consideral many of the (doubtless happy) original expressions and statements in t printed report, so as to adapt it more to the conventional anatomical id of his colleagues.

As the truth of Oken's generalization began to be appreciated, it was reme bered, as is usually the case, that something like it had occurred before others. Autenrieth and Jean-Pierre Frank had alluded, in a general way, the analogy between the skull and the vertebral column: Ulrich, reproduci formally, Oken's more matured opinions on the cranial vertebræ, say "Kielmeyerum præceptorem pie venerandum quamvis vertebram tanqua caput integrum considerari posse in scholis anatomicis docentem audiv And the essential idea was doubtless present to Kielmeyer's mind, thoug he reversed M. Duméril's proposition, and, instead of calling the skull a ve tebra, he said each vertebra might be called a skull. But these anticipatio detract nothing from the merit of the first definite proposition of the theor It would rather be an argument against its truth, if some approximative id had not suggested itself to other observers of nature, who only lost the me of developing it, from not appreciating its full importance. He, howeve becomes the true discoverer who establishes the truth: and the sign of t proof is the general acceptance. Whoever, therefore, resumes the investiga tion of a neglected or repudiated doctrine, elicits its true demonstration and discovers and explains the nature of the errors that have led to its tac

* Annales des Sciences Naturelles, t. iii. 1824, p. 177.

[illegible]

[illegible]

sens, le styloïde, les branches de l'hyoïde, qui sont ordinairement formés plus ou moins grand nombre de pièces placées bout à bout. Quelqu ces appendices sont libres à leur extrémité, d'autres fois ils se réunis dans la ligne médiane inférieure en entr'elles, ou au moyen d'une pièce diane, qu'on peut comparée, jusqu'à un certain point, au corps des tèbres; d'ou il résulte ce qu'on nomme 'sternum' dans les mammif appareil branchial des poissons, hyoïde, sternum des oiseaux," etc. (*ib.*] p. 110). Reserving the consideration of some of these propositions f subsequent chapter of the present work, I shall only notice, *en passant*, complete concordance between these views of the general homology of locomotive members with those which Oken expresses with his usual a ristic brevity:—"Freye Bewegungsorgane können nichts anderes als gewordene Rippen seyn."

Cuvier includes amongst the general characters of the class *Mammalia* arrangement of their cranial bones into three annular segments, correspon essentially with those of which Oken had demonstrated the vertebral relati "Leur crâne se subdivise comme en trois ceintures formées; l'antérie par les deux frontaux et l'ethmoïde; l'intermédiaire, par les pariétaux e sphénoïde; la postérieure, par l'occipital: entre l'occipital les pariétau le sphénoïde, sont intercalés les temporaux, dont une partie appartient pro ment à la face*."

What M. de Blainville (1816) pledges his efforts to demonstrate, O (Isis, 1817) was exulting in the reception of, 'not only in Germany but Europe.' "Seit Erscheinung dieser Schrift und nun 10 Jahre verflossen Man spricht nun von Kopfwirbeln, Kopfarmen und Füssen, von Bedeut der einzelnen Skeletknochen wie von einer uralten Sache; die schon in Bibel und den Propheten gestanden," p. 1204. The chief differences, compared with Oken's definition, are, that Cuvier, finding the frontal a to rest upon both ethmoïd and presphenoid, assigns to the former bone completion of the anterior cranial cincture below; and completes, in l manner, the parietal cincture by the sphenoid in its anthropotomical sen making no distinction between the anterior and the posterior divisions of bone. Cuvier does not apply this principle of arrangement of the cran bones to the skull of the lower classes of vertebrata (in which, neverthele it is more clearly manifested than in mammals): in generalising on the co stitution of the vertebrate skull, he classifies the bones, after the anthropo mists, into 'those of the cranium which encompass the brain, and those the face, which consist of the two jaws and the receptacles of the organs sense.'† With regard to the skull of fishes, in which Bojanus had found clear an illustration and confirmation of the Okenian views, Cuvier mer says, it is almost always divisible into the same number of bones as th of other ovipara. The frontal is composed of six pieces; the parietal three; the occipital of five; five of the pieces of the sphenoid and two of ea of the temporals remain in the composition of the cranium‡.

In his great works the 'Histoire des Poissons' and the 'Leçons d'An tomie Comparée,' posthumous edition, Cuvier expresses more decidedly h objections to the views of the segmental or vertebral structure of the skull.

Göthe, in a small fasciculus of 'Essays of Comparative Anatomy,' whic he published in the year 1820, entitles the 8th, "Can the bones of the sku

* Règne Animal, 8vo, 1817, t. i. p. 62.

† "La tête est formée du crâne, qui renferme le cerveau, et de la face, qui se compo des deux mâchoires et des receptacles des organes des sens."—Règne Animal, i. ed. 181 p. 62; ed. 1829, p. 52.

‡ *l. c.* ii. (1817), p. 107; (1829), p. 125.

duced from those of the vertebral column, and thence receive an ex-
tion of their forms and functions?" He states that the idea of the
facial vertebræ occurred to him in the year 1790, prior to which time
ys "die drei hintersten erkennt ich bald." The idea is developed in his
as follows:—"The skull of mammalia is composed of six vertebræ;
for the hinder division inclosing the cerebral treasure; three composing
re part which opens in presence of the exterior world, which it seizes
ntroduces.

The first three vertebræ are admitted (he alludes to Oken and Spix):
are,—

The occipital.

The posterior sphenoid.

The anterior sphenoid.

The three others are not yet admitted; they are,—

The palatine bone.

The upper maxillary.

The intermaxillary.

If some of the eminent men who ardently cultivate this subject should
nterested by this simple enunciation of the problem, and would illus-
it by some figures indicating by signs and ciphers the mutual relations
ecret affinities of the bones, its publication would strongly draw the
ing mind in that direction, and we may, perhaps, one day, ourselves
some notes on the mode of considering and treating these questions."

ofessor Carus of Dresden has best responded to this appeal of his im-
al countryman: but it must be admitted that the detailed and complex
ition of the theory of the six vertebræ and intervertebræ, of which the
al results are given in Table III., have yielded to anatomical science a
which is hardly equivalent to the zeal and pains manifested in the at-
, or to the artistic merit of the illustrations, published by the accom-
d author of the 'Urtheilen des Knochen und Schalengerüstes' (fol.
).

offroy St. Hilaire deems the skeleton of the head to be composed of
vertebræ; and he has the merit of having more steadily sought the
logies of the inferior arches of the cranial vertebræ than his predeces-
who seem not to have sufficiently appreciated the essential character of
portions of the primary segments of the vertebrate endo-skeleton.
rtheless it must be admitted that Cuvier has made good the grounds of
jection of Geoffroy's theory, as one based less on observation than on
y *à priori* views, according to which the bones of the skull, real or
inary, are arranged into seven vertebræ, composed of nine pieces each*.
cranio-vertebral system of Geoffroy is liable to the further objection,
he has combined, as in the case of his typical vertebra from the tail of
ounder, parts of the exo-skeleton (*e.g.* the suborbitals) with parts of
ndo-skeleton to which alone the vertebral theory is applicable.

the fasciculi of the magnificent 'Ostéographie' with which Professor de
ville has enriched his science, the descriptions follow the plan of the
fication of the bones of the skeleton propounded in the above-cited Me-
in the 'Bulletin des Sciences' for 1816 and 1817. In the Prospectus of
Ostéographie', M. de Blainville briefly refers to the great questions of
arative anatomy, which the German organologists have comprehended
r the name of '*Signification of the Skeleton*,' in allusion only to the
ss errors and opinions almost extravagant, of some of the persons who
occupied themselves with these questions:" whilst he reprobates, on the

* Cuvier, Histoire des Poissons, 4to, t. i. p. 230.

other hand, in equally general terms, "those who have been unable to themselves to these kind of questions, partly on account of the nature (minds, partly from the want of proper and sufficient subjects of cont tion *."

Neither the first step, the most difficult of all, nor any of the succ steps in the acquisition of such views of the 'Signification of the Sk as M. de Blainville adopts are noticed: no objection to the vertebral of the skull is answered: no error that may have opposed itself to a rec of the doctrine is explained or refuted: of the particular labours a coveries of individual homologists the author of the 'Ostéographie' is He defines a vertebra, in the language of anthropotomy, as a single bo "Une vertèbre, considérée d'une manière générale, et par conséquen son état complet, est un os court, médian, symmétrique, formant un partie principale de la vertèbre, aux deux faces opposées de laquelle, e on dorsale, interne ou ventrale, s'applique un arc plus ou moins déve d'ou résultent deux canaux, l'un au dos, l'autre au ventre." (*ib.* fasc. i. We discern the influence of the ideas of his ingenious contemporary, Ge St. Hilaire, in the admission of the ventral or inferior, as well as the dor superior arch; and, like Geoffroy, he recognises the physiological rel of the upper arch to the protection of the nervous system, and that o lower arch to the protection of the vascular system: but, overlooking jecting the idea of the relation of the ribs as the inferior protecting arcl the expanded central organ of the vascular system, he considers the ve (hæmal) arches as arriving at their maximum of development in the tail. dorsal and thoracic vertebræ are, accordingly, characterized as those whic provided with costiform appendages diversely articulated to them; looking, I may remark, the costal appendages of the cervical vertebræ i saurians and those which become anchylosed to the cervical vertebr birds, as do, frequently, their serial homologues to the dorsal vertebræ i same class. M. de Blainville seems, also, wholly ignorant of the fact that bent-forward ends of the long transverse processes of the lumbar vertebr the hares, cavies, and many other rodents, are primarily developed as dist costal rudiments: the same rudiments of lumbar ribs are found in the fo of the hog, and in the first lumbar vertebra of many mammals †. "Les l baires," says M. de Blainville, "n'ont plus de côtes, même incomplètes."

The ribs not being regarded as essentially parts of the inferior or hæ arches of vertebræ, the sternal bones which complete these greatly expan arches are accordingly regarded as a distinct series of bones, and cal 'sternebers.' M. de Blainville, as we have seen, had before (1817) compa them to vertebral bodies. In the 'Ostéographie,' however, he rightly rega the body of the hyoid as their serial homologue, but does not extend his co parison to the bones that in like manner complete the mandibular and m illary arches. These, with the cornua of the hyoid, and the sternal and ver bral ribs, he classes with the bones of the extremities, under the name appendages (appendices), adopting, in his larger work, as in his original ess essentially the idea of Oken, that the locomotive members are liberated rib

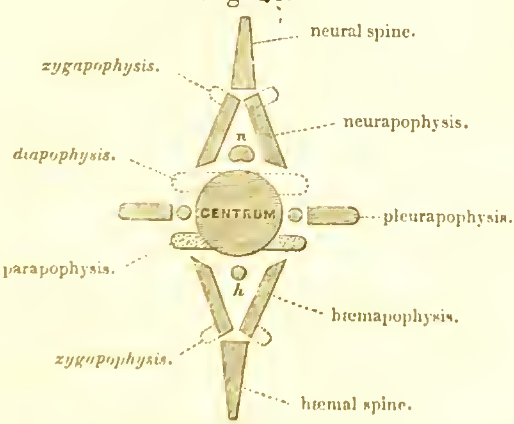
The Typical Vertebra.—After much additional research and comparis since the first publication of my ideas of the constitution of the typical ve tebra or primary segment of the endoskeleton ‡, I have found no reason f modifying them, but have derived additional evidence of their accuracy; a I therefore reproduce the diagrammatic figure with which they were original

* Ostéographie, Prospectus, April, 1839, p. 5.
† Thirle, in Müller's Archiv fur Physiologie, 1839, p. 106.
‡ Geological Transactions, 4to, 1838, p. 518.

rated (fig. 14). Although my investigations of the fundamental type e vertebrate skeleton were first made upon the class of fishes, where vege- e uniformity or irrelative repetition most prevails, and where, therefore, ype is least obscured by the modification of one part in mutual subser- y with another, I soon found that I should be led astray by confining my vations to fishes, and by borrowing illustrations from that class exclu- r. Comparison of the piscine skeleton with those of the higher animals nstrates that the natural arrangement of the parts of the endoskeleton is series of segments succeeding each other in the axis of the body. These ents are not, indeed, composed of the same number of bones in any class roughout any individual animal. But certain parts of each segment do tain such constancy in their existence, relation, position, and offices, as force the conviction that they are homologous parts, both in the consti- series of the same individual skeleton, and throughout the series of brate animals. For each of these primary segments of the skeleton I the term 'vertebra'; but with as little reference to its primary signifi- n, as a part specially adapted for rotatory motion, as when the compa- anatomist speaks of a sacral vertebra. The word may, however, seem anthropotomist to be used in a different or more extended sense than n which it is usually understood; yet he is himself, unconsciously perhaps, habit of including in certain vertebræ of the human body, elements he excludes from the idea in other natural segments of the same kind, nced by differences of proportion and coalescence, which are the most ble characters of a bone. Thus the rib of a cervical vertebra is the 'pro- s transversus perforatus,' or the 'radix anticus processus transversi verte- olli'*: whilst in the chest, it is 'costa,' or 'pars ossea costæ.' But the ulna l an ulna in the horse, although it be small and anchylosed to the radius. e osteology of man, therefore, cannot be fully or rightly understood the type of which it is a modification is known, and the first step to nowledge is the determination of the vertebral segments, or natural s of bones, of which the myelencephalous skeleton consists.

efine a vertebra, as *one of those segments of the endo-skeleton which con- the axis of the body, and the protecting canals of the nervous and lar trunks*: such a segment may also support *diverging appendages*. sive of these, it consists, in its typical completeness, of the following nts and parts :—

Fig. 14.



Ideal typical vertebra.

* Soemmerring, De Corporis Humani Fabricâ, 1791, i. p. 239.

The names printed in roman type signify those parts which, being usu developed from distinct and independent centres, I have termed 'auto nous' elements. The italics denote the parts, more properly called cesses, which shoot out as continuations from some of the preceding eleme and are termed 'exogenous': *e.g.* the diapophyses or upper 'transv processes,' and the zygapophyses, or the 'oblique' or 'articular processes human anatomy.

The autogenous processes generally circumscribe holes about the centr which, in the chain of vertebræ, form canals. The most constant and ex sive canal is that (fig. 14, *n*) formed above the centrum, for the lodgme the trunk of the nervous system (neural axis) by the parts thence ter 'neurapophyses.' The second canal (fig. 14, *h*), below the centrum, i its entire extent more irregular and interrupted; it lodges the central or and large trunks of the vascular system (hæmal axis), and is usually for by the laminæ, thence termed 'hæmapophyses.' At the sides of the trum, most commonly in the cervical region, a canal is circumscribed by pleurapophysis or costal process, by the parapophysis, or lower transv process, and by the diapophysis, or upper transverse process, which c includes a vessel, and often also a nerve.

Thus a typical or perfect vertebra, with all its elements, presents canals or perforations about a common centre; such a vertebra we fin the thorax of man and most of the higher classes of vertebrates, als the neck of many birds. In the tails of most reptiles and mammals, hæmapophyses (as in fig. 14) are articulated or anchylosed to the u part of the centrum; space being needed there only for the ca artery and vein. But where the central organ of circulation is to lodged, an expansion of the hæmal arch takes place, analogous to that w the neural arches of the cranial vertebræ present for the lodgment of the brain. Accordingly in the thorax, the pleurapophyses (fig. 15, *pl*) are much elongated, and the hæmapophyses (fig. 15, *h*) are removed from the centrum, and are articulated to the distal ends of the pleurapophyses; the bony hoop being completed by the intercalation of the hæmal spine (fig. 15, *hs*) between the ends of the hæmapophyses. And this spine is here sometimes as widely expanded (in the thorax of birds and chelonians, for example) as is the neural spine (parietal bone or bones) of the middle cranial vertebra in mammals. In both cases, also, it may be developed from two lateral halves, and a bony intermuscular crest may be extended from the mid-line, as in the skull of the hyæna, and the breast-bone of the bird (fig. 15, *hs*). To facilitate the comparison of the merits of the preceding view and nomenclature of the typical vertebra with those of other comparative anatomists, I have thrown the results into the form given in Table II.

Fig. 15.

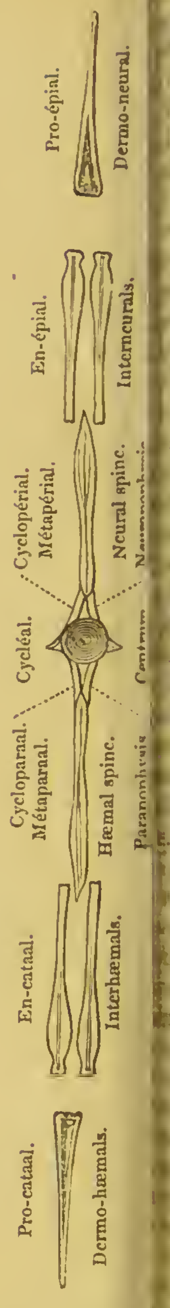
Natural typical vertebra: thorax of a bird.

) the question why I should have invented new names when Geoffroy St.
ire had already proposed others for the vertebral elements, I can only re-
the regret with which I found myself compelled to that invidious step,
having arrived at the conviction, that the learned Parisian Professor had
times applied the same term to two distinct elements, and sometimes
distinct names to one and the same element: and I am glad to be able to
the authority of Cuvier for the propriety and advantage of such a step.
words are in reference to an analogous case, "Donner à un mot connu un
nouveau est toujours un procédé dangereux, et, si l'on avoit besoin
primer une idée nouvelle, il vaudroit encore mieux inventer un nouveau
e, que d'en détourner ainsi un ancien *." Now there is scarcely one term
e first column in Table II. which is synonymous with its opposite in the
nd column, or which expresses exactly the same idea; and the discrepancy
mes greater in regard to the terms applied to the vertebral elements of the
, in columns 1 and 5 of Table III. The respective concordance of the views
e vertebral archetype entertained by Geoffroy and myself with Nature will
etermined and judged of by succeeding impartial and original observers.
ith regard to the term *cycléal*, "de *κύκλος*, cercle, pour rappeler sa
e annulaire, permanentes chez les premiers," (Articulata, Dermoverte-
, Geoff.) "et, au contraire, non persévérante chez les derniers" (Verte-
ı, Hauts-vertébrés, Geoff.), it is understood by its author to apply to the
lar segment of the crust of the insect, as well as to the 'centrum' of the
skeletal vertebra. Geoffroy's primary division of the parts of a vertebra
to the centre or nucleus (noyau) and the lateral branches. The upper
nches laterales' or 'périaux' are equivalent to my neurapophyses and
to my neural spine, in fishes: the lower lateral branches or 'paraaux' are
etimes free and floating†, when they answer to my 'pleurapophyses';
they are sometimes so united as to form a canal, when they answer
ny 'parapophyses' in the tail of fishes ‡, and to my 'hæmapophyses' in
ail of cetaceans. Geoffroy supposed, for example, that the hæmal canal
e tail in all fishes was formed by the ribs, bent down and anchylosed
oth ends§, and that the hæmal canal in the tail of the crocodile and
e was constituted by a like metamorphosis of the same vertebral elements.
also, argued that, as the small spinal chord of fishes did not demand
reat a development in breadth of the neurapophyses, they were permitted
tain to unusual length; and that, coalescing together, they thus consti-
l not only the neural arch but the neural spine, to which latter, therefore,
xtended the name 'périal'; whilst to the corresponding part in mammals
gives the name of 'épial'. But, again, in fishes, he calls the dermal
es developed in the embryonic median fold of integument which is meta-
phosed into the dorsal fins, 'épiaux'; and the corresponding dermal spines
e ventral fin 'cataaux.' The lepidosiren, however, manifests the neural
e distinct from both the neurapophyses below and the dermo-neural spine
ve: and such neural spine is unequivocally homologous with the anchy-
d neural spine in osseous fishes ||. It is quite in harmony with the position
e class of fishes at the bottom of the vertebrate scale that they should
ent a greater degree of calcification of the parts belonging to the same
gory of the skeletal system as the shells and crusts of the invertebrates;
ce it is that whilst the median dermal fins of the marine mammalia have

Mémoires du Muséum, t. xx. p. 123.
As they are illustrated in the abdominal vertebra of the fish figured by Geoffroy in the
moires du Muséum,' t. ix. (1822), pl. 5, fig. 4, polypterus, *o*. ‡ *Ib.* fig. 2, *o o*.
This occurs as an exceptional condition, in the lepidosteus, and perhaps in the lepido-
ı. || Linn. Trans. vol. xviii. p. 23, fig. 4, *c*, *d*.

their supporting skeleton in the primitive histological fibrous state, the corresponding parts are ossified in fishes: rarely, however, are such parts in answerable number to the vertebræ; and the true spines of these vertebræ, when the median fins and their bony spines are removed, in fishes, show as little indication of the place or existence of such fins, as do the vertebræ in the porpoise of the existence of its dermal fin. In proportion as ossification has extended into the dermal system of fishes it has been arrested in the vertebræ, which in the trunk and tail of fishes present their least complex condition. Two of the autogenous elements, the 'hæmapophyses,' are absent, and are commonly represented, in the tail, by the modified 'parapophyses.' The seeming complexity of a fish's vertebra arises from the intercalation of bones appertaining to the system of the dermo-skeleton: it would have been an unusual exception to the general course of development if the lowest of the vertebrate classes should have presented the vertebral skeleton in its highest state of complication; and Geoffroy St. Hilaire was unfortunate in taking a fish's vertebra with its extrinsic evertebrate complications, as the perfect type of that primary segment of the myelencephalous skeleton (fig. 16). He was still more unlucky in having for the subject of his figure* a specimen from which two of the pieces had been accidentally lost, as Cuvier afterwards pointed out; yet Geoffroy's mutilated caudal vertebra of the plaice continues to be copied in some compilations of comparative anatomy, as the type of a vertebra! To obtain the dermal spines (pro-epial and procataal) of the vertically extended caudal vertebræ of fishes, Geoffroy had recourse to a hypothetical division lengthwise of the interneural and interhæmal spines (which are represented as being single in his figure), and to as gratuitous a displacement of one of the halves from the side to the summit of the other †. Now the interneural and interhæmal spines are actually double in relation to the neural and hæmal spines; yet they coexist with a dermoneural and dermohæmal ray, which therefore needs no imaginary change of place of either of its supporting spines to account for its existence. I subjoin in fig. 16 an entire vertebra answering to the mutilated one figured by Geoffroy; and for the better understanding of the difference between his determinations of the vertebral elements and those given in the present work, the names respectively indicating those different determinations are added to the figure. In the description of the plate in the 'Mémoires du Muséum,' Geoffroy explains that the 'pro-épial' is the left half or 'épial *gauche*,' and the en-épial the right half or 'épial *droit*': that the en-cataal is the right half or 'cataal *droit*,' and the pro-cataal the left half or 'cataal *gauche*,' of imaginarily divided epivertebral and catavertebral elements (*l. c.* p. 115).

Fig. 16



Endo- and exo-skeletal elements of a caudal vertebra of a Plaice (*Pleuronectes*).

* Mémoires du Muséum, t. ix. (1822), pl. 5, fig. 1.

† "L'une de ces pièces monte sur l'autre"—"l'une se maintient en dedans, quand l'autre s'élance en dehors," *ib.* p. 97.

ıe trunk of fishes, in respect of its viscera and the degree of development e endoskeleton, answers to the lumbar and caudal regions of air-breath- 'ertebrates, where the vertebræ usually lose some of their elements, at as bones. The heart and respiratory organs are placed in the head of ish; and it is only in this region that the vertebral segments attain to al completeness in that class. Geoffroy, in studying the special and ral homologies of the bones of the head of fishes, blends indiscrimi- y, as in the supposed typical vertebra from the tail, elements of the oskeleton (suborbitals and lacrymals, *e. g.*) with those of the endo- ton; and also presses the capsules of the special organs of sense into the osition of the seven cranial vertebræ of his system. It needs only to are the synonyms of the elements of these vertebræ in Table III. to eive how impossible it would have been to have expressed the ideas h I wish to expound and illustrate in the present work by the use of the s for the vertebral elements proposed by Geoffroy, or of english equi- ts. The prefrontals, *e. g.* (no. 14), which I regard as the neurapophyses e nasal vertebra, are, according to Geoffroy, epials of the 2nd or labial bra in the class of fishes; but are epials of the 1st or nasal vertebra in rocodile, according to the tables given in the 'Annales des Sciences,' t. iii. and 'Atlas,' p. 44; whilst they are the perials of the 2nd vertebra in cheme of 1825, cited in the fifth column of Table III.

ıave deemed it requisite to enter the more fully into the grounds for doning the analysis and nomenclature of the typical vertebra proposed eoffroy, because they have received the sanction in this country of the ed Professor of Comparative Anatomy at University College. Dr. Grant* erts the French names into English equivalent phrases; 'cyclo-vertebral ent' for *cycléal*, 'perivertebral element' for *périal*, &c.; and abandons dvantage of a definite name, without remedying the disadvantages of ouble employment of the same names for two distinct elements, and of pplication of different phrases for the same element. If, for example, eural spine of the reptile or mammal be, in nature, the homologue of eural spine of the fish, then the latter is called an 'epivertebral element,' t the former is called a 'perivertebral element.' If the dermo-neural s of the dorsal fin of a fish be, in nature, homologous with the fibro- ıentous tissue supporting the dorsal fin of the dolphin, then the term 'ertebral element' is applied to a spine of the exoskeleton in the fish, and pine of the endoskeleton in the mammal, which spine co-exists with such al spine in the fish (see fig. 16). If the parapophysis or inferior transverse ess in the fish be a distinct element from the diapophysis or superior verse process in the mammal, the same phrase, 'paravertebral element,' lied to each. Dr. Grant, moreover, gives the same name, 'catavertebral ents,' to the free vertebral ribs in fig. 28, B. *g.* p. 58, *op. cit.*, as he applies ıe hæmapophyses in the tail of the reptile or cetacean, in fig. 28, C. *g.* *it.*; whilst Geoffroy applies the name 'cataaux' to the sternal ribs, and o the vertebral ribs: as the caudal vertebræ of the menopome (fig. 28) that it is with the sternal ribs that the chevron bones in the tails of rep- and cetaceans are homologous, both parts are 'hæmapophyses' in my m. The transference of the term 'catavertebral elements' (for *cataaux*), the 'côtes sternales' to the pair of ribs extended from the ends of the pophyses of the abdomen of fishes, is a deviation from the original ver- l system of Geoffroy, which seems to lead further away from nature. If meant that the outstretched parapophyses in the diagram of the abdominal bra of a fish (fig. 28, B. *f. f. loc. cit.*), and which are there called 'para-

* Outlines of Comparative Anatomy, 1835, pp. 57–59.

vertebral elements,' are the homologues of the 'côtes vertébrales' of h vertebrates, to which Geoffroy assigned the name 'paraaux,' this appe be another misapprehension of the relations in question.

Development of vertebræ.—Before applying the idea of the arche vertebra, or primary segment of the endo-skeleton, given in figs. 14 an to the elucidation of the modifications of those segments in the differen tebrate classes, I shall premise a few observations on the mode of dev ment of the vertebræ in those classes.

The chief condition of the development of distinct vertebræ in the is the conjunction of nerves with, or their progress from the spinal c at least, this circumstance, with the concomitant exit of blood-vessels the neural canal, seems to determine the development of the neurapoph and the vertebral bodies are not slow in coinciding in number with thos portant arches; and in determining with the regular primary pairs of (costal, lumbar, &c.) arteries, the inferior or hæmal arches. We may learn much the development of the neurapophyses and vertebral bodies dep in the trunk, upon the conjunction of nerves with the spinal chord, b fact that, in the regenerated tails of lizards, the vertebral axis remains tinuous and unjointed, because there is no co-extensive spinal chord g off pairs of nerves.

An extremely delicate fibrous band, with successively accumulated g nous cells, compacted in the form of a cylindrical column, and inclosed membranous sheath, is the primitive basis, called 'notochord'* (*chorda d lis* seu *gelatinosa*, Lat., *gallertsäule* und *ruckensaite*, Germ.), in and ar which are developed the cartilaginous or osseous elements by which vertebral column is established in every class of *Myelencephala*.

The earlier stages of vertebral development are permanently represe with individual peculiarities superinduced, in the lower forms of the cla fishes†. In the *Dermopteri* or cyclostomous fishes, the neural and ha canals are formed by a separation of the layers of the outer part of the neurotic sheath of the gelatinous chorda: in the lancelet (*Amphioxus*) t is no distinction of structure in the cranial part supporting the anterior of the neural axis, with which the trigeminal, optic and olfactory nerves c municate, and the rest of the rudimental vertebral column: a labial c laginous arch supporting the tentacula is, at least, the only lineamen development which sketches out the skull. In the myxinoids the skul cludes a complex system of cartilages, but the vertebral column of the tr has not advanced beyond the gelatino-aponeurotic stage. In the lam cartilaginous laminæ are developed in the outer layer of the fibrous she and give the first indication of neural arches‡. In the sturgeons (*St Polyodon*) the inner layer of the fibrous capsule of the gelatinous notoc has increased in thickness, and assumed the texture of tough hyaline ca lage. In the outer layer are developed distinct, firm, and opake ca lages, the neurapophyses, which consist of two superimposed pieces on e side, the basal portion bounding the neural canal, the apical portion parallel canal filled by fibrous elastic ligament and adipose tissue; above is the single cartilaginous neural spine. The parapophyses are now stinctly developed, and joined together by a continuous expanded base, fo ing an inverted arch beneath the notochord for the vascular trunks, ever the abdomen. Pleurapophyses are articulated by ligament to the ends of

* Νῶτος *back*, χορδή, *string*. We have hitherto had no English equivalent for this bryonic keel or basis of every vertebrate animal: 'dorsal chord' or 'chorda' is liable be misunderstood for the 'spinal chord.'

† Hunterian Lectures on Vertebrata, 1846, pp. 45, 46.

‡ Cuvier, Mémoires du Muséum d'Histoire Naturelle, t. i. 1815, p. 130.

ally projecting parapophyses in the first twelve or twenty abdominal ver-
æ: in the anterior ones these 'vertebral ribs' are composed of two or
distinct cartilages* : the posterior pleurapophyses are short and simple.
parapophyses gradually bend down to form hæmal arches in the tail, at
nd of which we find hæmal cartilaginous spines corresponding to the
al spines above. The tapering anterior end of the notochord is con-
d forwards into the basal elements of the cranial vertebræ. Vegetative
tition of perivertebral parts not only manifests itself in the composite
apophyses and pleurapophyses, but in a small accessory (interneural) car-
e, at the fore and back part of the base of the neurapophysis; and by a
ar (interhæmal) one at the fore and back part of most of the parapo-
es†.

mongst the sharks (*Squalidæ*) a beautiful progression in the further
lopment of a vertebra has been traced out, chiefly by J. Müller‡. In
anchus (*Squalus cinereus*) the vertebral centres are feebly and vege-
ely marked out by numerous slender rings of hard cartilage in the noto-
dal capsule, the number of vertebræ being more definitively indicated by
neurapophyses and parapophyses; but these remain cartilaginous. In
iked dog-fish (*Acanthias*) and the spotted dog-fish (*Scyllium*) the ver-
l centres coincide in number with the neural arches, and are defined by
n layer of bone, which forms the conical articular cavity at each end:
vhole exterior of the centrum is covered by soft cartilage, except at the
ave ends; the two thin funnel-shaped plates of osseous matter coalesce
ıeir perforated apices, and form a basis of the vertebral body like an
-glass; the series of these centrums protecting a continuous moniliform
ıant of the gelatinous notochord. In the great basking-shark (*Selache*)
vertebral bodies are chiefly established by the terminal bony cones, the
: margins of which give attachment to the elastic capsules containing
gelatinous fluid, which now tensely fills the intervertebral biconical spaces.
sub-compressed conical cavities extend, two from the bases of the
apophyses, and two from those of the parapophyses, towards the centre
ıe vertebral body, contracting as they penetrate it. These cavities always
ıin filled by a clear cartilage: the central two-thirds of the rest of the
ebral body contain concentric, progressively decreasing, and minutely
orated rings or cylinders of bone, interrupted by the four depressions:
peripheral third of the vertebral body contains longitudinal bony laminæ,
h radiate, perpendicularly to the plane of the outermost cylinder, to the
ımference; these outer laminæ lie, therefore, parallel with the axis of the
ebra, and the intervening fissures, like those between the concentric cylin-
within, are filled by clear cartilage, which shrinks, and leaves them open
e dry vertebra§.

ı *Cestracion* the intermediate part of the centrum between the terminal
s is strengthened by longitudinal radiating plates only; in *Squatina* by
entric cylinders only. In the tope (*Galeus*) all the space between the
ınal bony cones is ossified, except the four conical cavities, the bases
hich are closed by the neur- and par-apophyses; so that the whole
rior of the centrum appears formed by smooth compact bone.

ı the osseous fishes I find that the centrum is usually ossified from six
ts, four of which commence, as Rathke‖ describes, in the bases of the

Brandt & Ratzeburg, Medizinische Zoologie, 4to, 1833, t. ii. pl. iv. fig. 1.
Hunterian Lectures on Vertebrata, 1846, p. 53, fig. 12.
See Agassiz, Recherches sur les Poiss. Foss. t. iii. pp. 361, 369.
Hunterian Lectures on Vertebrata, 1836, p. 55, fig. 13.
Abhandlungen zur Bildungs und Entwickelungsgeschichte, Zweiter Theil. 1833, p. 41.

two neurapophyses and the two parapophyses ; but the terminal concave of the centrum are separately ossified. They coalesce with the intern part of the centrum, which is sometimes completely ossified, but comm communicating aperture is left between the two terminal cones ; a many cases, the plates by which calcification attains the periphery body leave interspaces permanently occupied by cartilage, forming e in the dried vertebra, especially at their under part, or giving a reti surface to the sides of the centrum. The expanded bases of the neu par-apophyses usually soon become confluent with the bony centrum ; times first expanding so as wholly to inclose it, as, for example, in the where the line of demarcation may always be seen at the border of th cular concavity, though it is quite obliterated at the centre, as a s through that part demonstrates.

Müller correctly distinguishes a 'central' from a 'peripheral' (cortica or seat of the ossification of the vertebral bodies of fishes. The peri ossification which takes its rise from the outer layer of the fibrous she the notochord sometimes extends into broad plates beneath the anterio tebræ of the trunk, and tends to fix or anchylose a certain number of when they are commonly represented by the partially distinct central of the bodies, together with the neur- and par- and pleur-apophyses.

The batrachia follow closely the stages above-cited in fishes ; the cen being arrested at the biconical stage in the perennibranchiates, but conv into ball-and-socket vertebræ by the ossification of the interposed gela ball* and its adhesion, either to the fore-part of the centrum (*Pipa*, *mandra*), or the back part (*Rana*, *Bufo*). The mode of ossification centrum varies somewhat in batrachia. Müller† describes annular eations in the sheath of the notochord of the *Rana temporaria* and *R. lenta*, which support, at first, the neurapophyses. Dugés, apparentl fluenced by M. Serres' so-called 'law of centripetal development,' des two cartilaginous nuclei, side by side; but the more obvious and bette termined development of the vertebræ of fishes gives no countenance t bilateral beginning of ossification of the centrum as a general law. Th distinct bony nucleus in the centrum observed by Dugés was bilobed afterwards cubical ; but excavated before and behind, as well as bene The ossification of the centrum is completed by an extension of bone the bases of the neurapophyses, which effect, also, the coalescence of with the centrum. In *Pelobates fuscus*, and *Pelobates cultripes*, Müller f the entire centrum ossified from this source, without any independent p of ossification.

The vertebræ of the tail of the larvæ of the anourans are represente stinctly only in the aponeurotic stage. Even when the change to cart takes place, the tendency to coalescence has begun to operate, and only long neurapophyses are established on each side : the ossification of t plates extends into the fibrous sheath of the remnant of the coccygeal n chord, and they coalesce when the perishable parts of the tadpole-tail l been absorbed, and the fore- and hind-legs developed, constituting the l often hollow, and inferiorly grooved coccygeal bony style.

In saurians, birds and mammals, the notochord is inclosed by carti before ossification begins ; which cartilage is continuous with the cartil nous neurapophyses§. In birds, the two histological processes, chondri

* Dutrochet, Mémoires pour servir à l'Histoire Nat. et Physiol. des Animaux, &c., p. 302. 1837.

† Neurologie der Myxinoiden, 1840, p. 69.

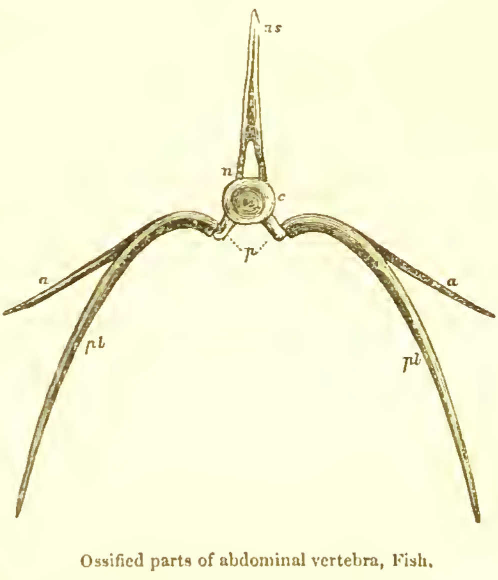
‡ Recherches sur les Batraciens, 1835, 4to, p. 106.

§ Müller, Vergleichende Anatomie der Myxinoiden, Neurologie, 1840, p. 74.

and ossification, do not precisely follow the same route. In the centrums he dorsal and cervical vertebræ of the chick chondrification is centripetal: egins from two points at the sides and proceeds inwards, the middle line he under surface of the primitive notochord resisting the change longest. , when the lateral cartilages have here coalesced, ossification begins at middle line and diverges laterally; the primitive nuclei of the bony centres earing as bilobed ossicles, and its direction is centrifugal. The lobes end to embrace the shrivelled remnant of the chorda, like the hollow ver-al centres in fishes. Only in the sacral vertebræ has ossification been 1 to begin from two distinct points at the middle line. The bases of separately ossifying neurapophyses extend over much of the centrum, soon coalesce with it. In reptiles a greater proportion of the centrum ssified from an independent point, and the bases of the neurapophyses n remain permanently distinct and united to the centrum by suture. In nmals, as in fishes, the centrum is ossified from an anterior and posterior tre, establishing the articular surfaces, as well as from an intermediate it. This is considerably overlapped by the bases of the neurapophyses, ore they coalesce with the centrum. The three primitive parts of the trum remain longest distinct in the cetacea. The body of the human s is sometimes ossified from two, rarely from three, distinct centres placed by side *. From these ascertained diversities in the mode of formation he central element of the vertebra, it will be seen how little developmental racters can be relied on as affecting the determination of homologous parts.

General Characters of Vertebræ of the Trunk.—The ossified parts of the lominal vertebræ of osseous fishes answer to *c*, centrum; *n*, neurapo-ses; *n s*, neural spine; *p*, parapophyses; *pl*, pleurapophyses; and *a*, ap-idages (fig. 17).

Fig. 17.



Ossified parts of abdominal vertebra, Fish.

The neurapophyses com-nly coalesce with their re-ctive centrums; except in case of the atlas, where the ral arch is sometimes quite arated from the centrum, l wedged between those of occiput and second verte-1. I have found also the rapophyses of the two last idal vertebræ unanchylosed their centrums in a large 1-perch (*Centropristis gigas*,) in which the five terminal mal arches and spines re-ined similarly distinct, and iculated with the centrums low. In the carp and pike, primitive independence of th neurapophyses and par-ophyses is more general and ger maintained. In the le-losiren the vertebral bodies are not developed, the notochord being per-tent; but the peripheral vertebral elements are well-ossified: the neur-ophyses in this fish remain distinct from the neural spines; and the hæmal ines are in like manner moveably articulated to the hæmal arches. These

* Meckel, Archiv für die Physiologie, Bd. i. (1815) t. vi. fig. 1.

are formed by the gradually bent-down ribs*, which are formed i abdomen either by unusally elongated 'parapophyses' (if they be preted by the condition of those elements in the cod-fish), or by pleu physes articulated directly to the fibrous sheath of the notochord; interpretation of the mode of formation of the hæmal arches is support Professor Müller's discovery of the nature of those arches in the *Lepidost* Whether we adopt the analogy of the *Anacanthini*, or the *Ganoidei* the general affinity of the *Protopteri* to the ganoids would incline the c to the latter), the constitution of the hæmal arches in the lepidosir strictly piscine; at least if we take the skeleton of the tailed batr (fig. 28) as our guide to the homology of the caudal inferior arch higher reptiles and mammals. The unusual size and length of the a minal parapophyses in the cod-tribe (*Gadidæ*), the flat-fishes (*Pleuronect* and the genus *Ophidium*, evinces the natural character of the order *Ana thini*, in which they have been grouped together by Professor Müller: pleurapophyses are, conversely, very short and slender in this order. I bony fishes the costal arch in the abdomen is completed by the aponeu septa between the ventral portions of the myocommata‡, which there re sent the 'hæmapophyses' (*cartilagines costæ, inscriptiones tendineæ musc. abdominis* of anthropotomy). Indeed, when we reflect that the trun the fish, by reason of the advanced position of the heart and breathing org answers to the abdominal and caudal regions of the trunk of higher ve brates, we could hardly expect the typical vertebra to be there carried o osseous tissue; but rather be prepared to find the hæmapophyses retai the same primitive histological state which they present in the abdome mammals and man (fig. 25, h'').

Immediately behind the coracoid arch, it is usual to find a long and sle rib-like bone, sometimes composed of two pieces, on each side; it giv firmer implantation to the portion of the myocommata immediately beh the pectoral fin; and is obviously the ossified serial homologue of the hæ pophysial aponeuroses between the succeeding myocommata. It is usu detached from its centrum and articulated superiorly to the inner side of coracoid: when it rises higher, as in the *Batrachus*, it becomes attache the atlas, and in the *Argyreiosus vomer* it meets and joins its fellow bel forming a true inverted or hæmal arch, parallel with, but more slender t the coracoid arch. No other idea of the general homology of this arch p sents itself than as a hæmal one, completing the costal arch as an ossif hæmapophysis, differing from the typical vertebra (fig. 15) only by the n development of a sternum or hæmal spine: and there appears to be as lit ground for hesitation as to the particular segment of the endoskeleton to wh to refer this costal or inverted arch; its immediate succession to the correspo ing arch attached to the occiput, as well as the occasional direct attachme indicating that segment to be the atlas or first vertebra of the trunk.

The best-marked general character of the vertebral column of the trunk the class *Pisces* is that which Professor J. Müller first pointed out; viz. t formation of the hæmal arches in the tail by the gradual bending down a coalescence of the parapophyses; the exceptions being offered by the gano polypterus and lepidosteus and the protopterous lepidosiren. The pleurap physes are, sometimes, continued in ordinary osseous fishes from the parap physes after the transmutation of these into the hæmal arches. The dor

* Linn. Trans. vol. xviii. pl. 23, fig. 4, *x x*.

† Remarks on the Structure of the Ganoidei, in Taylor's Scientific Memoirs, vol. i p. 551.

‡ Lectures on Vertebrata, 1846, p. 163, fig. 44, *h p*.

ry, and salmon yield this striking refutation of the idea of the formation hose arches in all fishes, by displaced, curtailed and approximated ribs. In e fishes, however (*e.g.* the cod), reduced pleurapophyses coalesce with the pophyses to form the hæmal arches of the caudal vertebræ. The meno-e, amongst the lowest or perennibranchiate reptiles, yields a clear disproof he formation of the hæmal arch in the tail by the pleurapophyses (the s, viz. called by Geoffroy 'paraux,' and by Dr. Grant 'catavertebral ele-ts' in the abdomen of fishes)*. The vertebral ribs or pleurapophyses in menopome (fig. 28, *pl*) are short and simple and suspended to the extre-es of the diapophyses (*d*) at the beginning of the tail, where they coexist ı hæmal arches (*h*, *h*) : these must be formed, therefore, by different ele-ıts, which, since no trace of parapophyses exists in any part of the spine, onclude to be the 'hæmapophyses.' The young crocodile and the adult iosaurs give the same evidence of the nature of the hæmal arches in the with which the corresponding arches or chevron-bones, in cetacea and ıy other mammalia, are homologous.

'hus the contracted hæmal arch in the caudal region of the body may be ned by different elements of the typical vertebra : *e.g.* by the parapophyses nes generally) ; by the pleurapophyses (lepidosiren) ; by both parapophy-and pleurapophyses (*Sudis*, *Lepidosteus*), and by hæmapophyses, shortened directly articulated with the centrums (reptiles and mammals)†. The dal vertebræ of some flat-fishes (*Pleuronectidæ*, fig. 16), and the mu-næ, would seem to disprove the parapophysial homology of the hæmal arches such fishes, since transverse processes from the sides of the body coexist ı them, as they do in the cetacea. But, if we trace the vertebral modifi-ons throughout the entire column in any of these fishes, we shall find that hæmal arches are actually parts of the transverse processes, not independ-elements, as in the cetacea ; but due to a progressive bifurcation : this, in *ræna Helena*, for example, begins at the end of the transverse processes ıbout the twenty-fifth vertebra, the forks diverging as the fissure deepens, il, at about the seventy-third, the lower fork descends at a right angle to upper one (which remains to represent the transverse process), and, eting its fellow, forms the hæmal arch, and supports the antero-posteriorly panded hæmal spine. In the plaice a small process is given off from the panded base of the descending parapophysis of the first caudal vertebra, ich increases in length in the second, rises upon the side of the body in third, becomes distinct from the parapophysis in the fourth, and gradually ninishes to the ninth or tenth caudal vertebra, when it disappears. These ırious transverse processes never support ribs.

The neurapophyses are often directly perforated by the nerves in fishes, t are sometimes notched by them, or the nerves issue at their interspaces.

The neurapophyses, which do not advance beyond the cartilaginous stage in e sturgeon, consist in that fish of two distinct pieces of cartilage; and the an-ior pleurapophyses also consist of two or more cartilages, set end on end: and s interesting compound condition is repeated in cases where the pleurapo-ysial element is ossified and required to perform unusual functions in the ny state in other fishes. Amongst the more special or exceptional modifi-tions of the vertebræ of the trunk of fishes, which indicate the extent to ıich their normal segmental character may be marked, I would cite those of e anterior vertebræ in the pipe-fishes, in the loaches, and in certain siluroids. In the *Fistularia tabaccaria* (Pl. 1, fig. 6) the four anterior vertebræ are ıch elongated; the second one even to eight times the length of the or-

* Outlines of Comparative Anatomy, p. 58, fig. 28, B, *g*.

† By a misconception of the sense in which I use the term 'hæmapophyses,' M. Agassiz s applied it to the laminæ of the inferior or hæmal arches in fishes. "Recherches sur les iss. Foss." tom. i. p. 95.

dinary abdominal vertebræ: and their centrums (*c*) are firmly interl together, by very deeply indented sutures. The parapophyses (*p*) ar extended with the centrums, and overlap each other, forming a contin outstanding horizontal ridge on each side; and the neural spines (*n s*) fo similar vertical continuous crest.

In the *Cobitis fossilis* and *C. barbatula* the par- and pleur-apophyse fig. 7, *p*) of the second and third vertebræ coalesce and swell out into a 'bulla ossea' on each side, inclosing the small air-bladder of these fis they also lodge the little ossicles which bring this vertebral tympanum communication with the prolongations or *atria* of the labyrinth*.

In a large South American siluroid fish (*ib.* figs. 3 and 4), I found fore-part of the vertebral column of the trunk apparently formed by one l vertebra, the body of which sent a broad triangular plate outwards on side, giving it a rhomboïdal figure, viewed from below: these plates in fish support and coalesce with five parapophyses (*p*, 5, 4, 3, *x*, *a*), which as and increase in breadth as they approach the skull, where they join the pa cipitals (*p o*), as they are, themselves, joined together so as to form a tinuous broad oblique outstanding plate of bone. Above these, the continu bony neural arch is perforated for the exit of five pairs of nerves; the do and ventral roots escaping separately, as in the sacrum of birds (fig.3, *n x*, *n* The coalesced neural spines send up a lofty pointed plate to the overhang supraoccipital. On vertically bisecting this specimen, I found the central p of the bodies of five vertebræ (*c*, *a*, *x*, 3, 4, 5) which had been develope the notochord, distinctly marked out, and preserving in their anterior posterior deep concavities the persistent gelatinous remains of the notoch although the rest of the circumference of such centrums were anchylo to the cortical or peripheral parts developed from the capsule of the no chord, viz. to the continuous expanded plate of bone (*c e*) below, to the pa pophyses laterally, and to the neurapophyses above. The body of the f vertebra, or atlas (*c a*), presented the exception of being quite detached fr its elevated parapophyses, as well as from its neural arch; it was anchylo only to the bony plate below. The body of the second vertebra was six ti as long as that of the atlas: yet the apices of the two deep terminal jel filled cones extended to and met in its centre. The bodies of the third a fourth vertebræ were elongated, but less so than that of the axis: the body the fifth vertebra (*c* 5) was singularly modified; its anterior half presenting long and slender character of the antecedent vertebræ; whilst the poster half was suddenly shortened, but extended in depth and breadth so as adapt its shallow posterior concavity to that of the short and broad body the first free vertebra of the trunk, which is followed by others of simi character. I have seen few more remarkable instances of adherence to ty irrespective of obvious function, than the persistence of the biconcave ar cular cavities, with the elastic capsules and contained fluid, in the centru of these five rigidly fixed anterior vertebræ of the siluroid fish.

The continuous bony plate supporting those centrums was perforat lengthwise by the aorta, offering another mode of formation of a hæmal can (*c h*), viz. by exogenous ossification in and from the lower part of the outer lay of the capsule of the notochord: the carotid hæmal canal in the necks birds seems to be similarly formed; and the neck of the ichthyosaurus deriv additional strength and fixation from apparently detached developments bone in the lower part of the capsule of the notochord, at the inferior inte space between the occiput and atlas, and at those of two or three succeedin cervical vertebræ †.

* Weber, G. H., De Aure et Auditu Hominis et Animalium, 4to. 1820.
† Sir Philip de M. Grey Egerton, in Geol. Trans. 2nd ser. vol. v. p. 187, pl. 14.

The so-called 'body of the atlas' in recent saurians, birds, mammals and 1, is the homologue of the first of these subvertebral wedge-bones, and resents only the inferior cortical part of such body. The odontoid pro- s of the axis is the central and main part of the body of the atlas. It not be the anterior articular epiphysis of the second vertebra, since this epresented by a distinct centre of ossification between the odontoid process l the body of that vertebra, according to Professor Müller's observation foetal foal*, and the odontoid exists in birds and reptiles in which the lies of the vertebræ have no terminal epiphyses as in young mammals.

The diverging appendages of the hæmal arch in the abdominal vertebræ of es present the form of long and slender spines (fig. 17, *a a*), usually at- hed to, or near the head of the ribs, and extending upwards, outwards l backwards, between the dorsal and lateral portions of the muscular ments, to which they afford a firmer fulcrum or basis of attachment; ing, therefore, as so many pairs of rudimental and concealed limbs. They termed the 'obere rippe' by Meckel, and at the fore-part of the abdomen the polypterus they are stronger than the pleurapophyses themselves. the vertebræ approach the tail these appendages are often transferred dually, from the pleurapophysis to the parapophysis, or even to the cen- m and neural arch.

In the air-breathing vertebrata, in which the heart and breathing organs transferred backwards to the trunk, the corresponding osseous segments the skeleton are in most instances developed to their typical complete- s, in order to encompass and protect those organs. The thoracic hæmapo- yses in the crocodiles are partially ossified, and in birds (fig. 15, *h*, *h*) com- tely so; in which class the hæmal spines of the thorax (*hs*) coalesce together, come much expanded laterally, and usually develope a median crest down- rds to increase the surface of attachment for the great muscles of flight. is speciality is indicated by the name 'sternum' applied to the confluent ments in question. The abdominal hæmapophyses and spines retain their mitive aponeurotic condition, though still preserving their characteristic pansion †. In the crocodiles and enaliosaurs the abdominal hæmapophyses also ossified; and, in the latter, they manifest the same composite character ich has been noticed in the pleurapophyses of the sturgeon, consisting of ee or more pieces, which overlap each other ‡. The abdominal hæmal nes, in the *Plesiosaurus Hawkinsii*, are transversely extended, they are rked *a*, *c* in the figure quoted below: the compound hæmapophyses them- ves are marked *b b* in the same figure.

The typical thoracic vertebræ of birds support diverging appendages (fig. , *a*, *a*), either anchylosed as in most, or articulated as in the penguin and teryx, to the posterior border of the pleurapophysis (*pl*). The function of appendages in this form of typical vertebra is to connect one hæmal arch th the next in succession, so as to associate the two in action, and to give mness and strength to the whole thoracic cage. (A portion of the next so overlapped is shown at *pl*, *a*, fig. 15.)

With regard to the connections of the pleurapophyses, we have seen that, fishes, they may be directly attached to the centrum, or to the ends of the rapophyses (fig. 17, *p*), or they may be quite detached from their proper seg- ent, and suspended to the hæmal arch of another vertebra, as in the case the clavicle (fig. 25, 52'). In batrachians, ophidians, and lacertians, the oximal end of the pleurapophysis is simple, as in fishes, but is articulated

* Vergleichende Anatomie der Myxinoiden. Abhand. Akad. der Wissensch. Berlin, 34, p. 105.
† Myology of Apteryx, Zool. Trans., vol. iii. pt. iv. pl. 35, *g**, *g**.
‡ Buckland, Bridgewater Treatise, vol. ii. pl. 18, fig. 3.

to an exogenous tubercle or transverse process from the side of the cen or from the base of the neural arch, called 'diapophysis,' which is a dis part from the autogenous parapophyses in fishes. The anterior vert of crocodiles have an exogenous inferior transverse process from the si the centrum, answering to the 'parapophysis,' as well as a superior trans process or 'diapophysis' developed from the base of the neurapophysis: the proximal end of the pleurapophysis bifurcates and articulates with transverse processes, circumscribing with them a foramen at the side o centrum. A similar structure obtains in the cervical and anterior tho vertebræ of birds and mammals: thus the rib (*pl*) in fig. 15 articulates wit parapophysis *p* and the diapophysis *d*. Very few, however, of the tho ribs in the cetaceans offer this structure; the first or second rib may reacl centrum, but the rest are appended to the ends of the long diapophyses, a character of affinity to the saurians is thus manifested. The cervica gion is distinguished by the shortness of the pleurapophyses and the abs of bony hæmapophyses, in saurians, birds, and mammals; but in the wa blooded classes the short floating vertebral ribs soon anchylose to the di physes and parapophyses, and constitute thereby the 'anterior roots of perforated transverse process' of anthropotomy*. The cervical pleur physes are indicated diagrammatically at *pl*, in the neck of the embryo sk ton (fig. 25): those of the seventh cervical vertebræ sometimes attain in human subject proportions which acquire for them the name of 'ribs.' pleurapophyses retain their moveable articulation in the ninth, and someti the eighth, vertebræ of the elongated neck of the three-toed sloths†.

The thoracic or dorsal vertebræ of mammalia are characterized by the free ticulations of the pleurapophyses (fig. 25, *pl*): most of these are much el gated, and most, if not all, support hæmapophyses (ib, *h*); which, in a grea or less number of the anterior vertebræ, articulate with hæmal spines (ib. completing the arch; these spines commonly remain distinct, and are cal some 'sternebers,' others 'manubrium,' and 'xiphoid appendage,' and gether they constitute the 'sternum.' In most mammals the thoracic ha apophyses are cartilaginous: they become ossified in *Dasypus*, *Myrmecopha* the megatherioids and monotremes. The hinder pleurapophyses, which p gressively diminish in length, also, usually become simply suspended to diapophyses; all the ribs are so attached in *Balæna longimana*, accord to Rudolphi. The lumbar vertebræ, which in some mammals show, in fœtal state, distinct rudiments of pleurapophyses more minute than th in the neck, have them soon anchylosed to the extremities of the diap physes, which are thus elongated; and the vertebra is characterized in anth potomy as 'having no ribs, but simple imperforate transverse processes.' T hæmapophyses of these segments of the skeleton are represented by t 'inscriptiones tendineæ' (fig. 25, *h''*); they do not advance even to the sta of cartilage, but retain the primitive condition which they presented in t corresponding part of the trunk in fishes.

If a vertebra succeeding the lumbar or abdominal ones have its hæm arch completed, as in the thorax, by pleurapophyses and hæmapophys with diverging appendages, forming the 'pelvic arch and hind or low limbs (fig. 28, D', H, A),' it is called a 'sacrum'. If two or more vertebi anchylose together, without such completion of the typical character, th likewise are said to form a 'sacrum,' of which an example may be found

* Meckel, Archiv für Physiologie, B. i. (1815) p. 594, pl. vi. fig. 12, *e*; and System der Ve gleichend. Anatomie, B. ii. p. 294.

† Prof. Th. Bell. Trans. Zool. Society, i. p. 115. pl. 116. *a*, *b*.

wo or three anterior caudal vertebræ of certain flat-fishes (*Pleuro-læ**), characterized as usual by the simple parapophysial hæmal arch. ɔst air-breathing vertebrates the sacrum is characterized by both modifica-, which are carried out to their extreme in birds: in no other class is so a proportion of the vertebral column converted into a 'sacrum' by scence (*e. g.* seventeen vertebræ in *Struthio*): in none is the diverging ndage developed to such enormous proportions (*e. g. Apteryx, Dinornis*). centrums of the middle sacral vertebræ (fig. 27, *c* 1–4) are expanded versely, but depressed, and converted into horizontal plates: the neur-hyses (*ib. n* 1–4) are lofty, expanded, and arch over the dilated part of ieural canal, lodging the great sacral enlargement of the myelon, with ntricle. In the young ostrich, before the general anchylosis is completed, ases of these neurapophyses are found to cross the interspaces of the rums, and to rest equally upon two of those elements. This modifica-was retained throughout life, unobliterated by anchylosis, in the sacrum ie extinct dinosaurs (*Iguanodon, Megalosaurus, Hylæosaurus*), and it ins in the dorsal vertebra of the chelonians. The adjoining portions ie centrums and neurapophysis extend outwards into a short parapo-is, which affords an articular surface of three facets for the short pleur-hysis. One of these elements is figured *in situ* at *pl*, fig. 27; it expands s distal end, and coalesces there with the contiguous pleurapophyses: ong diapophyses (*d, d*) abut against the inner side, and the ilium applies to the outer side of these expanded and anchylosed ends of the short il ribs. The spinous processes of the sacral vertebræ (*s, s*) are developed ro-posteriorly, and soon coalesce into a lofty longitudinal crest of bone. ie chelonians, the dorsal spines develope horizontal plates from their ex-iities, which unite by suture to the similarly united and expanded pleur-ɔhyses, forming with them the 'carapace.' The 'plastron' is formed of flattened and expanded hæmal spines, which are divided in the middle and have an intercalated bone (entosternal) between the halves of the ral pieces. Professor Müller has noticed the sacral pleurapophyses in human and other mammalian embryos†.

s the segments of the endo-skeleton approach the end of the tail, in the ɔreathing vertebrates, they are usually progressively simplified; first by diminution, coalescence and final loss of the pleurapophyses; next by the lar diminution and final removal of the hæmal and neural arches; and etimes also by the coalescence of the remaining central elements, either a long osseous style, as in the anourous batrachia, or into a shorter ened disc "which has the shape of a ploughshare‡," as in many birds. coalesced representative of the terminal vertebral centrums is developed cipally from the outer layer of the fibrous capsule of the primitive noto-rd. In fishes, however, the seat of the terminal degradation of the verte-column is first and chiefly in the central elements, which, in the homo-als§, are commonly blended together and shortened by absorption, whilst h neural and hæmal arches remain, with increased vertical extent, and cate the number of the metamorphosed or obliterated centrums.

Hunterian Lectures on Vertebrata, 1846, p. 65, fig. 22.

"Selbst am Kreuzbeine mehrere Thiere giebt es noch abgesonderte Querfortsätze oder ɔenrudimente."—Anatomie der Myxinoiden, heft i. 1834, p. 239.

"La dernière de toutes (des vertèbres de la queue), à laquelle les pennes sont attachées, plus grande et a la forme d'un soc de charrue, ou d'un disque comprimé:—dans le jeune elle est évidemment composée de plusieurs vertèbres."—Cuvier, Leçons d'Anat. Comp. ed. i. p. 208. and "Lawrence's Blumenbach's Comparative Anatomy," ed. 1827, p. 62.

M. Agassiz' expressive name for the fish with a symmetrical bilobed tail.

Summary of modifications of corporal vertebræ.—To sum up the ki degree of modification to which the several elements of the primary se of the endoskeleton of the trunk are subject, without masking their g homology, we may commence with the *centrum*; and first, as to its exi It is wanting, as an ossified part, in the atlas of the wombat and koa which it remains permanently cartilaginous: in the petaurists, kang and potoroos, ossification extends from the bases of the neurapophyse this cartilage, but the neural arch or ring long remains interrupted by dian fissure below. In man the rudimental body of the atlas is som ossified from two or even three distinct centres †. The centrums at the site extremity of the vertebral column in homocercal fishes are render centripetal shortening and bony confluence fewer in number than th sistent neural and hæmal arches of that part. The centrums do no beyond the primitive stage of the notochord in the existing lepidosiren they retained the like rudimental state in every fish whose remains have found in strata earlier than the permian æra in Geology, though the nu of vertebræ is frequently indicated in Devonian and Silurian ichthyolit the fossilized neur- and hæm-apophyses and their spines ‡. The individ of the centrums is sometimes lost by their mutual coalescence without s ening.

Although the normal form of the centrum is cylindrical, it may be cu conical, hour-glass shaped, like a longitudinal bar, like a transverse bar a depressed or a compressed plate, like a ploughshare, &c. The co-ad terminal surfaces of the centrum may be flat, slightly concave, deeply cave, cupped or conical, concave vertically and convex transversely at end and the reverse at the other end §; or the fore-end may be concave the hind-end convex ‖; or the reverse ¶; or both ends may be conve or both ends produced into long pointed processes with intervening dee sures, so as to interlock together by a deeply dentated sutural surface †

The centrum may be quite detached from its neural arch (atlas of sil and many fishes), and from its hæmal arch (atlas of most fishes).

The centrum may develope not only parapophyses but inferior me exogenous processes, either single, like those of the cervical vertebr saurians and ophidians (which in *Deirodon scaber* perforate the œsopha are capped by dentine, and serve as teeth ‡‡); or double (atlas of *Sudis gig* and the lower cervical vertebræ of many birds); or the fibrous sheath of notochord may develope a continuous plate of bone beneath two or more nu of centrums, formed by independent ossification in the body of the notoch these nuclei being partially coherent to the peripheral or cortical plate. vertebral centrum often shows the principle of vegetative repetition by partial ossification in the form of two or three bony rings, which answer single neural arch (*Heptanchus* ‖‖); or by three osseous discs, one for e

* Art. Marsupialia, Cyclopædia of Anatomy and Physiology, vol. iii. p. 277, fig. 99.
† Meckel, Archiv für Physiol. i. taf. vi. fig. 1.
‡ See the admirable Monograph by Agassiz, Sur les Poissons Fossiles du Système vonien, 4to, 1846.
§ Most birds.
‖ Existing saurians and ophidians.
¶ Extinct saurian called '*Streptospondylus*;' existing *Salamandra*, *Lepidosteus*.
** 4th cervical of *Emys*, Bojanus, Anat. Test. Europ., tab. xiv. fig. 51, 4. 1st cauda crocodile.
†† Cervicals or anterior trunk-vertebræ of *Fistularia*.
‡‡ Jourdan, cited in Cuvier's Leçons d'Anat. Comparée, ed. 1835, p. 340, and 'Odo graphy,' p. 179.
§§ Agassiz in Spix, Pisces Brasilienses, 4to, 1829, p. 6, tab. B, fig. 8.
‖‖ Müller and Agassiz, in Recherches sur les Poissons Fossiles, t. iii. tab. 40ᵇ, fig. 1.

lar surface, and a thicker intermediate piece, as in all fœtal mammals, iroughout life in some cetaceans.

th respect to function, the centrum forms the axis of the vertebral .n, and commonly the central bond of union of the peripheral elements vertebra: as a general rule it supports, either immediately or through edium of the approximated or conjoined bases of the neurapophyses, eural axis (iu the trunk called myelon, or spinal marrow, and its mem- s); the terminal centrums being usually deprived of this function by ithdrawal of that axis from them iu the course of its centripetal or con- itive movement.

; *neurapophyses* are more constant as osseous or cartilaginous elements vertebræ than the centrums; but they are absent, under both histolo- conditions, at the end of the tail in most air-breathing vertebrates, where gments are reduced to their central elements. The neurapophyses lose primitive individuality by various kinds and degrees of confluence; as rst, of the bases of each pair with their supporting centrum; secondly, apices of each pair with one another and with the neural spine,—the siren affording a rare exception of the persistent individuality of this nt and of each neurapophysis throughout the trunk; thirdly, of two re neural arches with one another, as in the neck of some fishes, cetacea, rmadillos, and in the sacrum of birds and mammals; where they also coalesce with the pleurapophyses, as they do in the neck of most mam- ind birds. The neurapophyses rarely depart from the form of plates, broad or high, or both; sometimes they are straight, sometimes arched, imes bent; sometimes by the inward extension of their bases, they form ier a bony ring above the centrum, excluding both that and the spine the neural canal. The neurapophyses may develope, as exogenous pro- , either diapophyses or zygapophyses, and the latter are sometimes e from both the anterior and posterior borders of the plates; as *e. g.* in ertebræ of *Mugil*, in some serpents, and in the lumbar vertebræ of some nals. The observed extent of variation of position of the neurapophyses n the upper surface of their own centrum to above the next intervertebral , so as to rest equally on two centrums; or they may be uplifted bodily their centrum, and wedged or suspended between the two contiguous l arches, as *e. g.* in the atlas of ephippus and other deep-bodied fishes. cept in the cartilaginous neurapophyses of the sturgeon, I am not aware y instance of the subdivision of this element into two pieces, placed ally upon each other. Some plagiostomes show the principle of vegetative ition in two or three star-like centres of ossification, side by side, in the tive basis of the neurapophysis, but the second of the two cartilaginous on each side of the neural canal, coextensive with the single centrum, st sharks, which second piece has the form of a wedge with the small lirected down over the intervertebral space, seems to answer, as Prof. er has suggested, to the intercalary or interneural piece in bony fishes.

e most constant functional relation of the neurapophysis is to protect inal nerve in its exit from the spinal canal, either by a direct perfora- of the neurapophysis (many fishes, and some mammals), by a notch in iargin, or by the interspace between two neurapophyses. This function is performed, in reference to the nervous system, at the posterior part e vertebral column in many animals, where the place of the shortened n is occupied by the lengthened roots of the nerves: in the rest of the the neurapophyses protect also the neural axis. The original relation h neurapophysis to the segments of that axis is determined by the place nection of the perforating nerve with the shortened myelon.

The *neural spine* commonly retains in the trunk the form indicated name; but in the atlas of the crocodile, where it is distinct from th apophyses, it is a depressed plate. In the thorax and abdomen of che it becomes still more expanded and flattened, and its borders unite by d suture to contiguous spines and to the similarly expanded pleurapo The neural spine is absent in the thin annular cervicals of the mol unusually developed and forms a thick square columnar mass of bone cervicals of the opossum. It is double in the anterior vertebræ o fishes: in the barbel one stands before the other; in the tetrodo stand side by side: and various other minor modifications of this per element might be cited.

The *parapophyses* of the trunk-vertebræ manifest their autogeno racter in fishes alone; and in most species the character is soon lost, tl apophyses becoming confluent with the centrum; and, in the tail, eith the pleurapophyses also, or with each other and the hæmal spine, thus c ting the hæmal canal (fig. 16). Amongst air-breathing vertebrates tl apophyses of the trunk-segments are present only in those species in the septum of the heart's ventricles is complete and imperforate, an they are exogenous and confined to the cervical and anterior thoracic ver or to the sacrum (as in the ostrich, figs. 15 and 27, *p*). The parapophy subject to a certain extent of variation as to form: they are eithe tubercles; or simple, shorter or longer, transverse processes; or they ma the form of long plicated laminæ (in the tails of some pleuronectidæ) are longer and broader than the pleurapophyses in the cod-tribe; a sometimes much expanded in the anterior vertebræ of fishes, where ascend in position, and in the siluroid species above described, coale form a broad outstanding ridge, directed outwards and a little upward rising as they approach the cranium, where they are joined by close sut the paroccipitals.

The normal function of the parapophyses is to give attachment to m and articulation to ribs, and, occasionally, additional strength and fixat anchylosed portions of the vertebral column. As a rare and exception stance, the expanded and excavated parapophyses of the second and vertebræ in the genus *Cobitis* perform an office closely analogous to c those of the mastoid in man, since they inclose air-cells brought into munication with the acoustic labyrinth by a chain of small ossicles: and singularly modified rudiments of the swim-bladder seem to have no other tion in the groveling loaches than that in connection with the sense of hea

The *pleurapophyses* are less constant elements than the neurapoph they exist as free appendages or 'floating vertebral ribs' in the trunk sometimes at the fore-part of the tail, in fishes, serpents, and certain b chians (fig. 28, *pl*). The atlas has its pleurapophyses in most fishes, but are often detached from their centrum, and sometimes joined to long hæmapophyses, as is well-seen in the *Argyreiosus*, and other deep-bc scomberoids. Ossified hæmapophyses are not present in any other vert of the trunk in fishes. In batrachians the pleurapophyses of the single p vertebra are similarly connected with hæmapophyses, and the costal ar there completed. In the menopome, the pleurapophysial element of the sac *ib. pl'*, is ossified from two centres. Such typical vertebræ are more com in the higher air-breathing classes. Here the pleurapophyses have gene the long and slender form understood by the word 'rib;' but they expand broad plates in the thorax of the apteryx, in the anterior thoracic verteb whales, and more especially in the carapace of chelonians, where they joined to each other by suture, and also to the expanded neural spines. Tl

.d pleurapophyses are oeeasionally ossified from two centres in the great -tortoises of India and the Galapagos isles. The free extremities of the t cervical pleurapophyses of crocodiles and plesiosaurs are expanded and luced forwards and backwards, like axe-blades, whence the name of chet-bones,' applied to them prior to the recognition of their true homo-.

he pleurapophyses are appended sometimes simply to the ends of par-›hyses; sometimes to the ends of diapophyses; sometimes by a head and ·rcle to both kinds of transverse processes; sometimes directly to the of the eentrum; and sometimes they are shifted backwards over the in-ertebral space, and are artieulated equally to two eentrums (human ax), and sometimes to two eentrums, to a neurapophysis and to a long ophysis, as in the saerum of the ostrieh (fig. 27, *pl*). In the atlas of e fishes the pleurapophysis is detached from its eentrum, and is suspended, . its hæmapophysis, from the anteeedent hæmal areh (scapulo-coracoid). ›ome sturgeons the abdominal pleurapophyses are composed of two or e cartilaginous pieees. I have observed some of the expanded pleurapo-ses in the great *Testudo elephantopus* ossified from two eentres, and the lting divisions contiuuing distinct but united by suture. The pelvic rapophysis is in two pieces, as a general rule (fig. 28, *pl'* attached to ; and the lower pieee is the seat of that most common and simple kind iodification, viz. inerease of size with change of form from the eylindrieal flat bone (as indieated by the dotted line in fig. 27), whereby it comes eonnection with the pleurapophyses of other vertebræ besides the proxi-pieee of its own; sueh pleurapophyses having their development stunted s not to exeeed in size the proximal portion of the pelvic pleurapophysis, se expanded distal portion (62) receives the speeial name of 'ilium.' This e retains its rib-like shape however in the chelonians, as in the batraehians: iost species it unites below with two hæmapophyses, ealled, on aceount heir modifieations of form and proportions, 'isehium' and 'pubis.' The irapophyses defend the hæmal or viseeral cavity; they are the fulera of moving powers which expand and eontraet such eavity in respiration, n its walls admit of those movements; they frequently support 'diverging endages,' and give origin to museles moving such appendages, or aeting n the vertebral eolumn. In some exeeptional cases the pleurapophyses ome, themselves, loeomotive organs, as in serpents and the *Draco volans.*

'he *hæmapophyses*, as osseous elements of a vertebra, are less eonstant than pleurapophyses; although they sometimes exist in segments, *e. g.* the bar vertebræ of certain saurians, and in the ease of the ischium, or second ic hæmapophysis, in whieh the corresponding pleurapophyses are absent, short, or anchylosed to the transverse proeesses. The only true bony napophyses in the trunk of fishes appear to be those of the atlas, forming lower pieee of the epieoracoid; and of the last (?) abdominal vertebra, ning the isehial or pubic inverted areh supporting the appendages ealled ntral fins.' It is at least to the last abdominal vertebra solely that the iologous arch and appendages are connected, by the medium of the irapophyses (iliac bones) in the batrachians, and it needs but the removal he pleurapophysis, or of its seeond complementary portion (*pl'* in fig. , to reduee that vertebral segment to the condition whieh it presents in an ominal fish. The so liberated inferior (hæmapophysial) portion of the ic (last abdominal eostal) arch is subjeet, in fishes, to changes of position more extensive than have been observed in the neurapophyses or pleur-physes of the trunk-vertebræ, without however preventing the reeognition he segment to which such shifted hæmapophyses actually and essentially belong. The homologous hæmal arch exists in the same free and det condition in cetaceans and enaliosaurs; but in all other air-breathing brates it is connected with the iliac bones and completes the typical cha of the proper sacral vertebra. The bony hæmapophyses of the lumbar ver are found suspended in the fleshy abdominal walls of certain saurians: the region of the thorax in these and higher vertebrates, the hæmapo (fig 15, *h*) articulates by one end to the pleurapophysis (*pl*) and other to the hæmal spine (sternal bone, *hs*); or its lower end is attach contiguous hæmapophysis; or it is suspended freely from the pleurapop (as in the 'floating ribs' of man and mammals), or it may be joined to the sternum, and have its upper end free, as in the seventh dorsal ver of the *Ciconia Argala*. When the upper end of the hæmapophysis artic with the pleurapophysis in birds, it is usually by a distinct condyloid with smooth articular cartilage and a synovial capsule.

Where hæmapophyses exist in the tail, they articulate directly t under part of the centrum, or to two centrums at the intervertebral s and are either free at the opposite end, as in some caudal vertebræ o pents and in those of the enaliosaurs, or they are confluent with each at their distal ends; when each pair of hæmapophyses forms the so-c V-shaped or chevron-bone. The changes of position of that detached ' arch' or 'chevron-bone' which supports the ventral fins in fishes affo Linnæus the characters of the orders 'Abdominales,' 'Thoracici,' 'Jugulares' in the 'Systema Naturæ'; and its immortal author, in giving name 'Apodes' to those fishes in which the ventral fins were absent, cisely indicates his perception of their relation to the hind-legs of batra and the lower limbs of man. If, then, mere change of relative posi however extensive, failed to conceal the special homology of the detached tion of the pelvic arch and its appendages from the keen-sighted natur still less ought such a character to blind the philosophic anatomist to general homology of such detached vertebral elements, or prevent his tra them, wherever he may find them, to the remainder of their proper segm especially when its place is so clearly and beautifully indicated, as it is by condition of the pelvic arch in the perennibranchiate reptiles (fig. 28).

The function of the hæmapophyses is to complete, with or without a hæ spine, the hæmal arch of the vertebral segment; and, in so far to protect hæmal or visceral cavities and support their contents. They give attachn to the lower or ventral portions of the primary muscular segments 'n commata'*, called 'intercostals' in the thorax, and 'recti abdominis' in abdomen of the higher vertebrata; and they thus serve as fulcra to muscles that expand and contract the abdominal or thoracic-abdominal cav and sometimes more directly aid in these movements by the clasticity resul from an arrest in their histological development at the cartilaginous stage, in the thorax of most mammals. Hæmapophyses may support or aid in s porting diverging appendages; and in giving attachment to the muscle those appendages. The hæmapophyses are usually slender, simple bo varying in length: they are broad, flat, and overlap each other in the tho of monotremes: they become broader and shorter in the expanded and fi thoracic abdominal bony case of chelonians, and are still broader where t close the pelvic arch in the plesiosaurs. In the abdominal region of these tinct saurians and in crocodiles, the freely suspended hæmapophyses are co pounded of two or more overlapping bony pieces.

* See the description of these segments, usually confounded under the name of the 'g lateral muscle' or 'longitudinal muscles' in fishes.—Hunterian Lectures on Vertebrata, pp. 163–165.

he *hæmal spine* is much less constant as to its existence, and is subject much greater range of variety, when present, than is its vertical homo- above, which completes the neural arch. Long, slender, and 'spinous' ie tail, the hæmal spine is reduced to a short and thick bone, often ened, in the thorax of mammals, a series of thirteen such modified spines ing the so-called 'sternum' in the two-toed sloth: the thoracic hæmal es are few in number, and are expanded and perforated in the whales: horizontal extension of this vertebral element is sometimes accompanied median division, or in other words, it is ossified from two lateral centres; s seen in the development of parts of the human sternum: the same vege- e character is constant in the broader thoracic hæmal spines of birds; gh, sometimes, as *e. g.* in the struthionidæ, ossification extends from the lateral centre lengthwise, *i. e.* forwards and backwards, calcifying the iate cartilaginous homologues of halves of four or five hæmal spines, re these finally coalesce with their fellows at the median line. In some r birds, however, there are two or more lateral centres, and usually, a median one, from which the ossification of the keel extends down- ls, prior to its confluence with the rest of the 'sternum.' In the thorax helonians four hæmal spines are established, each by two lateral centres ssification, forming four pairs of sternal bones with a ninth 'entosternal' e between the first and second pairs. The 'plastron' is the result of extreme development of the hæmal spines:—the modified moieties of ch, remaining permanently distinct and united by suture, have received Geoffroy St. Hilaire* the convenient special names of 'episternals,' sternals,' 'hyposternals' and 'xiphisternals,' respectively, as they suc- each other from before backwards.

he *diverging appendages* are, as might be expected, of all the elements ie vertebral segment, the least constant in regard to their existence, and subjects of the greatest amount and variety of modification. Simple ler spines or styles in fishes (fig. 17, *a a*), simple plates retaining long cartilaginous condition in crocodiles, short flat slightly curved pieces in s (fig. 15, *a a*), in some of the lowest species of which, *e. g. Aptenodytes*, become expanded, like their homologues in the crocodile; such, with exception, is the range of the variety of form to which these parts are ect in the segments of the trunk. But that exception is a remarkable : even under its normal ichthyic condition, as a simple style or filament, liverging appendage of the insulated hæmapophysial portion of the pelvic in the protopterus† and lepidosiren‡ is composed of many cartilaginous nents, and projects freely from the surface, carrying with it a smooth ring of integument. In other fishes similar filaments or jointed rays are gressively added to the sustaining arch, which cause a progressive expan- of the common investing fold of skin, forming the organ called the ntral fin,' which is accordingly described by the ichthyologist as having rays (*Blennius*), three rays (*Zoarces*), up to more than twenty rays, (as *penser* in the sturgeons).

Vhen we quit the piscine class we find the diverging appendage of the pel-

Du Sternum considérée dans les Oiseaux et dans les Poissons. Anatomie Philoso- ie, p. 69. pl. 2, fig. 21. Here Geoffroy contends that the parts of the hyoid arch (39, id 43) are the homologues of the modified hæmal spines which he calls episternals, hyo- als and hyposternals in the plastron of the turtle: but these names may well be retained, of 'hyosternal' being used in an arbitrary sense, without reference to the hypothesis h first suggested it.

Linn. Trans. vol. xviii. pl 23, fig. 1, *z*. Lectures on Vertebrata, p. 79, figs. 27, 66.
Bischoff, *op. cit.* pl. 2, fig. 5, *c*.

vic arch resuming its primitive unity, and with fewer joints than in lepid but manifesting the principle of vegetative repetition by a bifurcation distal segments. Such is its form in the *Proteus anguinus* and in the *A uma didactylum*: in another species of amphiume, the radiated type i strongly marked by the subdivision of the last segment into three ra homology of which with certain of the five terminal rays, called t digits in the human foot, is signified by Cuvier's specific name 'tridac' applied to this species; the middle segment of the appendage is bif first one is undivided. In the menopome (fig. 28), the proximal se (65) is likewise single, the second segment (66, 67) double, and a mass of lage (68) separates this from the last segment which branches into five j rays (69). In the frog two styliform bones are developed in the posi the cartilage (68 in fig. 27), forming a fourth segment of the division are replaced by more numerous and shorter bones in higher vertebra which it will be unnecessary to pursue the metamorphoses of the appe as it is adapted for swimming, steering, balancing and anchoring, for ex tion, for burrowing, creeping, walking and running, for leaping, sc climbing, or sustaining erect the entire frame of the animal. Its parts these endless and extreme modifications have necessarily received s names: the first segment (65) is the thigh, *femur*; the second is the le its two rays or bones are called *tibia* (66) and *fibula* (67): the segmen is called ankle or *tarsus*, each of its component ossicles having its p name; and the last radiated segment (69) includes the metatarsus and langes: the segments 68 and 69 are termed collectively, the foot, *pes**.

The primitive function of the simple diverging appendages (fig. 17, of the abdominal vertebræ in fishes is closely analogous to that of the developed appendage of the pelvic vertebra, viz. to aid in locomotic fulcra to the muscles concerned in that act. In crocodiles and birds serve to connect one costal arch with the next arch in succession, associ them in action or giving fixity and strength to the whole thoracic cage.

Any given appendage might, however, have been the seat of such dev ments as convert that of the pelvic arch into a locomotive limb: and the insight into the general homology of limbs leads us to recognise many p tial pairs in the typical endo-skeleton. The possible and conceivable r fications of the vertebrate archetype are far from having been exhaust the forms that have hitherto been recognised, from the primæval fish the palæozoic ocean of this planet up to the present time.

The beneficent Author of all, who has created other revolving orbs, relations to the central source of heat and light like our own, may have w that these also should be the seat of sentient beings, suited to all the ec tions of animal enjoyment existing in such planets; basking, perhaps, in solar beams by day, or disporting in the soft reflected light of their ea satellites by night. The eyes of such creatures, the laws of light being same, would doubtless be organized on the same dioptric principles as o and, if the vertebral column should there, as here, have been adopted as basis of the higher animal forms, it may be subject to modifications iss in forms such as this planet has never witnessed, and which can only be c ceived by him who has penetrated the mystery of the vertebrate archet and recognised the kind and mode and extent of its modifications here.

It is, for example, by no means essential to that organic type that it sh be 'tetrapodal': although it best accords with the force of attraction and o

* A remarkable example of the extent to which an early or low form of such segi may be regained by abnormal development in a higher species is given by Kerkrin, Opera Omnia, 4to. 1717, p. 55, tab. viii.

itions of our globe, that not more than two pairs of the latent limbs or ndages of the vertebral segments should be developed to react, as locove instruments, upon its waters, its atmosphere and its dry land.

ie views of the essential relations of such limbs to the vertebrate type h suggest these and similar reflections, may not be accepted by all anato-s: some may be disposed to regard the parts 62 and 64 in fig. 28 as pecu-uperadditions, rather than a reappearance of normal elements completing costal or hæmal arch of a segment of the endo-skeleton and restoring it s typical condition: and, in the same spirit, they may deny the special ology of the radiated appendage A, with the hinder filamentous fin of epidosiren, and the ventral fins of other fishes, and consequently, will re-ate its general homology as the diverging appendage of such hæmal , and its serial homology with the simple diverging appendages of the acic-abdominal vertebræ of fishes, crocodiles and birds.

am sensible how large a demand is made on the most philosophic faith in ral laws of organization, by seeking acquiescence in the view of the parts ie hind-limb, so variously and definitely modified for special functions, as g the homologues of segments and rays, which are the result in the first ance of the common course of vegetative repetition of a single vertebral ent—an element under all circumstances compounded teleologically, and, efore, essentially representing or equivalent to one bone.

ut here I must explain what I mean by 'teleological composition.' Indi-al parts of a skeleton,—what are commonly called 'bones,'—are fre-ntly 'compound' or composed of the coalescence of several primarily nct osseous pieces. In human anatomy every single and distinct mass sseous matter entering into the composition of the adult skeleton is called one'; and Soemmerring, who includes the thirty-two teeth in his enumera-, reckons up from 259 to 264 such bones. He counts the os spheno-pitale as a single bone, and also regards, with previous anthropotomists, os temporis, the os sacrum, and the os innominatum, as individual bones; sternum, he says, may include two or three bones, &c*. But in birds os occipitale is not only anchylosed to the sphenoid, but they both very i coalesce with the parietals and frontals; and, in short, the entire cranium ner consists, according to the above definition, of a single bone. Blu-bach, however, applying the human standard, describes it as composed he proper bones of the cranium consolidated, as it were, into a single e†. And in the same spirit most modern anthropotomists, influenced by comparatively late period at which the sphenoid becomes anchylosed to occipital in man, regard them as two essentially distinct bones. In direct-our survey downwards in the mammalian scale, we speedily meet with mples of persistent divisions of bones which are single in man. Thus it re to find the basioccipital confluent with the basisphenoid in mamma-quadrupeds; and before we quit that class we meet with adults in some he marsupial and monotrematous species, for example, in which the supra-ipital, 'pars occipitalis proprie sic dicta,' of Soemmerring, is distinct from condyloid parts, and these from the basilar or cuneiform process of the occipitis: in short, the single occipital bone in man is four bones in the ssum or echidna; and just as the human cranial bones lose their indivi-lity in the bird, so do those of the marsupial lose their individuality in the inary mammalian and human skull. In many mammals we find the rygoid processes of anthropotomy permanently distinct bones; even in

* De Corporis Humani Fabricâ, t. i. p. 6.

† Manual of Comparative Anatomy, by Lawrence, ed. 1827, p. 56.

birds, where the progress of ossific confluence is so general and rap pterygoids and tympanics, which are subordinate processes of other b man, are always independent bones.

In many mammals, the styloid, the auditory, the petrous, and the m processes remain distinct from the squamous plate of the temporal, th out life; and some of these claim the more to be regarded as distinct since they obviously belong to different natural groups of bones in the ske as the styloid process, for example, to the series of bones forming the dean arch.

The artificial character of the anthropotomical view of the os sacr which that more or less confluent congeries of modified neural arc counted as a single component bone of the skeleton, is sufficiently ol The os innominatum is represented throughout life in most reptiles by distinct bones, answering to the iliac, ischial, and pubic portions in a potomy. The sternum in most quadrupeds consists of one more bon the number of pairs of ribs which join it; thus it includes as many as th distinct bones in the *Bradypus didactylus*.

The arbitrary character of the definition of a bone, as 'any single pi osseous matter entering into the composition of the adult skeleton,' the plex nature of many of such single bones, and the essential individual some of the processes of bone in anthropotomy, are taught by anatomy perly so called, which reveals the true natural groups of bones, and the fications of these which peculiarly characterise the human subject.

It will occur to those who have studied human osteogeny, that the pa the single bones of anthropotomy which have been adduced as conti permanently distinct in lower animals, are originally distinct in the h fœtus: the occipital bone, for example, is ossified from four separate ce the pterygoid processes have distinct centres of ossification; the styloid the mastoid processes, and the tympanic ring, are separate parts in the f The constituent vertebræ of the sacrum remain longer distinct; and the i ischium, and pubes are still later in anchylosing together, to form the 'n less bone.'

These and the like correspondences between the points of ossificati the human fœtal skeleton, and the separate bones of the adult skeleto inferior animals, are pregnant with interest, and rank among the most king illustrations of unity of plan in the vertebrate organization.

The multiplication of centres from which the ossification of an ultim single bone often proceeds has especially attracted the attention of the p sophical anatomists of the present century with reference to the righ natural determination of the number of the constituent parts of the v brate skeleton. Geoffroy St. Hilaire, in his memoir on the skull of bird 1807, says, "Ayant imaginé de compter autant d'os qu'il y a de centres sification distincts, et ayant essayé de suite cette manière de faire, j'a lieu d'apprécier la justesse de cette idée*." Cuvier adopted and reta the same idea to the last. Commenting in the posthumous edition of 'Leçons d'Anatomie Comparée†' on the character of some of the de tions of single bones in anthropotomy, he, also, concludes that, in orde ascertain the true number of bones in each species, we must descend to primitive osseous centres as they are manifested in the fœtus. But accor to this rule we should count the humerus as three bones and the femur as

* Annales du Muséum, t. x. p. 344.

† Tom. i. 1835, p. 120. "Mais ces distinctions sont arbitraires, et pour avoir le vérit nombre des os de chaque espèce, il faut remonter jusqu'aux premiers noyaux osseux qu'ils se montrent dans le fœtus."

3, in the human skeleton; for the ossification of the thigh-bone begins at distinct points, one for the shaft, one for the head, one for the great auter, and one for the distal condyles: such deference, however, to the nent of the great Comparative Anatomist has been withheld by the most ted of his admirers; whose disinclination to regard these parts and pros as distinct bones is justified by the fact that in birds and reptiles the r is developed from a single centre.

ie rule laid down by the French authorities above-cited fails in its applin to the difficult question of the nature and number of bones in a skeleton, use they did not distinguish between those centres of ossification that homological relations, and those that have only teleological ones; *i. e.* een the separate points of ossification of a human bone which typify ebral elements, often permanently distinct bones in the lower animals; and eparate points which, without such signification, facilitate the progress steogeny and have for their obvious final cause the well-being of the growinimal. The young lamb or foal, for example, can stand on its four legs as as it is born; it uplifts its body from the ground and soon begins to and bound along. The shock to the limbs themselves is broken and nished at this tender age, by the divisions of the long bones, and by the position of the cushions of cartilage between the diaphyses and epiphy- And the jar that might affect the pulpy and largely developed brain of immature mammal, is further diffused and intercepted by the epiphysial cular extremities of the bodies of the vertebræ.

Ve thus readily discern a final purpose in the distinct centres of ossifica- of the vertebral bodies and the long bones of the limbs of mammals ch would not apply to the condition of the crawling reptiles. The dimive brain in these low and slow cold-blooded animals does not demand protection against concussion; neither does the mode of locomotion ie quadruped reptiles render such concussion likely: their limbs sprawl vards and push along the body which commonly sweeps the ground; efore we find no epiphyses at the ends of a distinct shaft in the long es of saurians and tortoises. But when the reptile moves by leaps, the principle of ossifying the long bone by distinct centres again pres, and the extremities of the humeri and femora long remain epiphyses he frog.

A final purpose is no doubt, also, subserved in most of the separate centres ossification which relate homologically to permanently distinct bones in general vertebrate series; it has long been recognised in relation to faciting birth in the human fœtus; but some facts will occur to the osteonist, of which the teleological explanation is by no means obvious.

One sees not, for example, why the process of the scapula which gives athment to the pectoralis minor, the coraco-brachialis, and the short head of biceps should not be developed by continuous ossification from the body the blade-bone, like that which forms the spinous process of the same ie. It is a well-known fact, however, that not only in man, but in all mamls, the coracoid process is ossified from a separate centre. In the monomes it is not only autogenous, but is as large a bone as in birds and reptiles, which it continues a distinct bone throughout life. Here, then, we have homological, without a teleological explanation of the separate centre for coracoid process in the ossification of the human blade-bone.

This distinction in the nature and relations of such centres is indispenle in the right application of the facts of osteogeny to the determination the number of essentially distinct bones in any given skeleton.

All those bones which consist of a coalescence of parts answering to dinct elements of the typical vertebra are 'homologically compound.'

All those bones which represent single vertebral elements are 'tel cally compound,' when developed from more than one centre, wheth centres subsequently coalesce, or remain distinct, or even become the of individual adaptive modifications, with special joints, muscles, &c. f ticular offices.

In the human skeleton, the clavicles, the (thoracic vertebral) ribs, stances of simple and truly individual bones. The occiput, sphenoi moid, temporal, superior maxilla, mandible, hyoid, scapula, the so-calle vertebræ, the sacrum and coccyx, the sternum, and ossa innomina 'homologically' compound bones.

The two parietals are essentially like the frontal and vomer, one 'tele cally' compound bone : so, likewise, are the two nasals. And, if the v the homology of the jointed filamentary skeleton of the rudimental v fin of the lepidosiren with the simple diverging appendages of the arches of the abdominal vertebræ be correct, then is not merely the malian femur a teleologically compound bone, but the whole skeleton hind-limb from the femur to the distal phalanges inclusive must be reg as representing the essentially single vertebral element, here called 'dive appendage,' subdivided according to the law of vegetative repetition of ce which law is progressively overruled and masked by the supervention higher law of special modification and adaptation of such vegetative su sions to the exigences and habits and sphere of life of the species.

In many animals all the parts of the skeleton of the limbs, and in al mals some of the parts, are simple bones, in the sense of being deve from a single centre ; but in none can they claim that essentially indiv character which the clavicles and osseous parts of the ribs are entitled being primary vertebral elements.

To trace the mode and kind and extent of modification of the same mentary parts of the typical segment throughout a large natural seri highly organized animals, like the vertebrata ; and to be thus led to appre how, without complete departure from the fundamental type, the specie adapted to their different offices in creation, brings us, as it were, int secret counsels that have directed the organizing forces*, and is one of legitimate courses of inquiry by which we may be permitted to gain a sight into the law which has governed the successive introduction of spe forms of living beings into this planet.

Vertebræ of the Skull.—Since it has been found that the bones of the tr maintain through every kind and degree of adaptive modification, whethe 'thorax,' 'carapace' or 'sacrum,' an arrangement into segments in the stitution and relative position of the parts of which the vertebral type has b universally recognised—let us next examine, without bias, and, if possi without reference to or recollection of previous attempts, in the first insta whether such type be traceable through the remaining anterior part of axis of the endo-skeleton, which, like the thorax and pelvis, has received account of its degree of coalescence and other modifications, the special lective term of 'skull ;'—or, whether nature has, in this part of the endo-s leton, so far departed from the pattern on which all the rest is construct that we cannot, without manifest violence to her arrangements, demonstr the segmental composition ; or refer, without admitting modifications disti in kind as well as degree from those that mark the vertebral character in trunk, the constitution of such segments to the vertebral type.

Taking the conical skull of an ordinary osseous fish—that of the cod (*M rhua vulgaris*) for example,—if we detach the bones which form its hin extremity, or base, and which immediately precede and join the atlas, fr

* " — præsens esse cum artifex operatur et opus suum promovet."—BACON.

next in advance, we have the circle, or the base bone (1) and arch 4), represented in figure 1, and we also bring away, articulated therewith, ferior or inverted arch with its appendages, represented in profile outline . 5, 50–57 : the arrow indicating the course of convergence, and its head oint of union, of the two flanks or crura, forming the closing point or u of such inverted arch.

e have thus removed a segment of the skull, and with as little or even violence or disturbance to the other bones, than must have been used in ching a similar segment from the thorax or pelvis of a land-animal. If ompare this cranial segment with the typical vertebra fig. 14, we recog- in the single median bone (1, fig. 1) the *centrum*, by its relative position its articular surface for the atlas, which retains, moreover, the concave characteristic of the vertebræ in the piscine class: in the pair of bones), which articulate with the upper surface of the centrum, protect the of the epencephalon, and are perforated by the 'nervi vagi,' we have the *apophyses*: in the single symmetrical bone (3) which completes the , and terminates in a crest for the attachment of the uppermost or dorsal ions of the vertebral muscles continued from the trunk, we have the *neural e*: and in the pair of bones (4, 4), wedged between this spine and the apophyses, which give attachment to the inferior arch of the segment 5, H i), and terminate in a free crest or spine for the attachment of the er and lateral portions of the vertebral muscles, we have the *parapo- ses*; for whose elevated position we have been prepared by their gradual nt in the anterior vertebræ of the trunk. The rest of this natural segment undergone the same kind of modification as the thoracic vertebræ present igher animals (fig. 15), and which consists in the great expansion of the nal arch, the removal of the *hæmapophyses* (fig. 5, 52) from the centrum 1), and the interposition of elongated and deflected *pleurapophyses* (50, 51): lly, the great inverted arch, so formed, encompasses, supports and protects heart, or centre of the hæmal axis. The elements of this arch are open wo interpretations according to the type of figure 15: either 50 may be 51, *h* and 52 *h s*; or 50 and 51 may be a divided (teleologically compound) urapophysis, and 52 an unusually developed hæmapophysis : and this latter clusion is more agreeable with the character of the vertebral segments of trunk in fishes, in which the hæmal spines are absent, the hæmapophyses, en ossified, long and sometimes joined together at their lower ends, as *e. g.* he first trunk-vertebra of *Argyreiosus vomer*, and the pleurapophyses some- es, as *e. g.* in the sturgeon, composed of two or more pieces, set end to l. The condition of the pleurapophysis of the pelvic arch in the meno- ne (fig. 28, 62, *pl*), which sustains a radiated appendage (*ib.* A) of the mal arch of the occipital vertebra, indicates the true character of the urapophysis: and the modifications of this arch in the higher classes will found to establish the accuracy of the general homology of the bone 52, h the hæmapophysial element, since the lower extremities of 52 are actu- y drawn apart and articulated to a hæmal spine, which completes the arch low in reptiles and birds (fig. 22, H *s*).

Even should there be error in assuming the subdivision of the pleurapo- yses and the absence of the hæmal spine, in the particular determination of constituent elements of the arch in question, yet the alternative is still thin the recognised limits of the vertebral modifications of the trunk; and want of unquestionable proof of the precise elements forms no valid ob- ction to its general homology as a hæmal vertebral arch, expanded and modi- d after one or other of the types of those which, in the thorax of the air- eathing vertebrates, encompass and protect the more backwardly placed centres of the vascular system (heart and lungs); according to whic for example, it may be either closed below by the meeting of the ster (hæmapophyses) or by the intervention of a single or divided stern (hæmal spine). And, further, since in fishes, as the lowest class of vert the vegetative character of repetition of forms, proportions and com in the successive segments of the skeleton prevails in a greater degre in any of the higher classes, so we may conclude that this hæmal arc sents, by its articulation with the epencephalic neural arch, its normal p and that the whole occipital vertebra here manifests its veritable and character.

As the hæmal arches in the trunk of fishes commonly support div appendages, which project freely outwards and backwards, but are hidd buried in the muscular masses to which they give attachment, so the oc arch, also, commonly supports its diverging appendages. They are in *Gymnothorax* and some other *Murænidæ*. The appendage is pres the form of a single multiarticulate filament in the eel-like protopterus lepidosiren†; it is modified by that mode of vegetative repetition results in adding to the number of similar filaments directly articula the supporting arch; and is further complicated by the expansion or c ence of the proximal joints in different degrees as they recede from th porting arch, so as to constitute definable segments of the appendage‡. Such is the condition of the part in most osseous fishes, and such is s in the diagram of the base of the appendage in figure *5*; where the pro segment consists of two broad and flat bones (54 and 55), the next segme five narrower and shorter but thicker bones (56), and the last segme more numerous bones of the primitive filamentary form and multiartic structure, which bifurcate and radiate as they recede from the centre tachment.

We may connect the tendency to extreme and variable development i peripheral parts of a vertebral segment, with the freedom which is the n sary consequence of their position: they are attached by one end only, have not, therefore, that physical restraint to growth which may arise o the fettering by both extremities, which characterizes the more central tebral elements entering into the composition of the neural and hæmal arc Even in these we find the disposition to luxuriant growth or vegetative division greatest in the peripheral elements, viz. the neural and hæmal spi much more, therefore, might it be expected in the less constant, diverg and commonly freely projecting appendages of the vertebral arches. Altho here the polarizing forces which tend to shoot out particle upon particle the pattern of dendritic corals, plants or crystals, are so controlled by antagonizing principle of adaptation, that the radiating growth is alw checked at that stage and guided to that form which is suited to the w and required by the mode of life of the species.

Since, however, we are able to retain firmly and with certitude our rec nition of the special homology of the diverging appendage of the occip hæmal arch, through all its modifications, from the single ray of the lepid ren to the hundred-fold repetition of the same elements with superad dichotomous bifurcations sustaining the enormous pectoral fins of broad and flat plagiostomous fishes thence called 'rays' *par excellence*, we can retrace, with equal certitude, the serial homology of this appenda when it is so plainly manifested by its simple form as well as connections

* Linnæan Transactions, vol. xviii. pl. 23, fig. 4, *w*.
† Bischoff, *Lepidosiren paradoxa*, 4to, pl. 2, fig. 4, *c*.
‡ Hunterian Lectures on Vertebrata, figs. 27, 40, 41, 42, 43, 75.

›idosiren, the amphiuma or the apteryx, with the scarcely more simple -developed appendage of the thoracic abdominal hæmal arches (ribs) ls and fishes (figs. 15 and 17, *a*, *a*) ; and thus we are led to determine ieral homology, under its manifold forms of fin, fore-limb, wing, or arm, diverging appendage of the hæmal arch of the occipital vertebra.

:natural and typical vertebral segment above-defined cannot be detached, ry fish, by the mere disjunction of sutures: in the lepidosiren, *e. g.* the d part of the centrum has coalesced with that of the next segment in ce and would require to be divided by the saw: the same coalescence ; in the human skull, and has led to the definition of the cranial bone, 'os spheno-occipitale*.' In osseous fishes, either by connation of 5 , fig. 5, or by excessive development of bone in the notochordal capsule ling forwards from the centrum 5, and producing 9, there results the long (5, 9) continuing the series of vertebral centrums forwards, and corre-ing in position with two segments or arches above. On the hypothesis represents the central elements of both those arches, it must be divided ially, in order to separate that segment of the cranium which next suc- the occipital one. And, further, either by a similar coalescence of the nal elements of two hæmal arches, or by the undue extension of such nt of one of the arches, interposing itself between the next arch and st of the vertebra to which that arch belongs, it happens, that unless the nal element or elements in question be artificially divided, as at 28*a*, 28*a*, two hæmal arches (H II and H III) would be brought away, with the l arch detached by the separation of sutures and the division of the 5, 9. If neither that bone, nor 28*a* were divided, but were, with the in superior connection with them, separated from the bones anteriorly lated to them by suture, then we should have the group of bones, in-l by the curved lines marked N II, N III, H II, H III in fig. 5. Two oral segments are plainly indicated in this group by the distinct hæmal s and their appendages, H II and H III; but three pairs of bones, 16, 6 ›, fig. 5, appear to be in neurapophysial relation with the single and etrical median bone 5, 9. If, however, what has been urged in the er on 'Special Homology' (pp. 188-196) respecting the petrosal cha- of 16 be a true interpretation of that bone, then we must eliminate it our present inquiry, inasmuch as being a partial ossification of a sense-le (and nature herself removes them, as such, in most fishes), it apper-to a category of bones (splanchno-skeleton), forming no part of the pro-euro- or endo-skeleton, in which alone we seek for evidence of a segmental sition of parts corresponding with the segments of the nervous system.

e bony petrosals (16) being removed, let us, then, with the view of ex-ing the composition of the segment of the skull with which the occipi-ertebra was articulated, saw across the bones 5, 9 and 28*a*, and separate ones 6, 7, 8 from their sutural connections with those in front of them. us obtaining the segment in question, the opponents to the vertebral y of the skull are entitled to assert that violence is done to nature by ections of the single bones above-cited; the validity of which as an tion to that theory will be afterwards inquired into.

is not, however, absolutely necessary to divide the basal bone 5, 9 : in osseous fishes a symmetrical bone (fig. 5, 9′) supports the parial bones nd stands in the relation of a centrum to them ; the neural arch or circle at segment would not, therefore, be broken by the removal with the rior segment of the whole of the bone 5, 9. If the corresponding

* See Table I., Soemmerring.

development from the under part of the centrum of the second cervi tebra of the siluroid fish (p. 260) were removed, with that segment, fi atlas, the atlantal neural arch would still be completed by the rudimenta beneath which the ossification from the succeeding vertebræ had ex itself.

Whether, however, we divide or not the bone 5, 9, those which res its posterior or basisphenoidal part present, after the removal of the sals, when viewed from behind, and slightly disarticulated from each the arrangement exhibited in fig. 2. The bones 6, 6 support and the lobe of the third ventricle or the mesencephalic segment of the they give exit to the trigeminal nerves (*tr*), and thus, as well as by the nections with the other bones of the arch, repeat the *neurapophysial* cha of the bones 2, 2 in the occipital segment. The bones 8, 8, by their mo ternal position, by affording an articular surface to the hæmal arch H 11), and their development of a strong transversely and backwardl duced process for muscular attachments, obviously repeat the *parapo* characters of the bones 4, 4 in the occipital vertebra.

The arch is not completed above in the cod-fish; the bones 7, 7 bei parated at the mesial line by the interposition of the produced spine occipital vertebra 3, which joins with 11. In some other fishes, how *e. g.* carp and pike, the bones 7, 7 do come in contact and join each otl a 'sagittal' suture, thus completing the neural arch. It will afterwa seen, by tracing the homologues of these bones in other animals and homotypes in other segments, what value may be assigned to the object their general homology as the crown or hæmal spine of the mesence neural arch, founded upon the median division and occasional divaricat the two halves of no. 7 in osseous fishes. I may so far anticipate the d sion as to remark that, even in the present group of vertebrates, the sp the occipital vertebra (3) is divided by a median suture in the lepidosteu that the condition of the epencephalic arch in that fish is precisely tl the mesencephalic arch in the carp, and essentially the same as that in 1 and in most other osseous fishes.

The remainder of the second or parietal segment of the skull, H 11, repea expanded modification of the hæmal arch of the occipital vertebra, and approaches nearer to the character of the thoracic vertebræ of the h animals, by the development of single symmetrical bones at the crown o inverted arch. But the principle of vegetative repetition is still more r fested in this arch than in the occipital one. If we regard the posterior of the epitympanic, 28*a*, as the proximal piece of the parieto-hæmal : which has coalesced with the corresponding piece of the fronto-hæmal : then the *pleurapophysis* of the parieto-hæmal arch will consist, in bony fi of two pieces, 28*a* and 38, like the pleurapophysis of the occipito-hæmal a 50 and 51. The bones, 39 and 40, represent the *hæmapophysis* of the parieto-ha arch. The two pairs of small bones (41) with the single median anterior and posterior (43) appendages, represent a still more subdivided spine or bone of this inverted arch.

Beneath this mask of multiplication of bony centres, the broad charac of the inverted arch suspended to the parapophyses of the parietal verte as the hæmal complement of that natural segment of the skull, stand bo out: it encompasses, sustains and protects the branchial organs—the a logues of lungs—the next great development of the vascular system ante to the heart; and the subdivision of the piers of this expanded arch relate the necessity for a combination of strength, with flexibility and elasticity the execution of the movements producing the respiratory currents.

ie correspondence with the scapular, or occipito-hæmal arch, is further ed out by the presence of *appendages* (44) which freely diverge from it, but evelopment of these appendages has not been observed to extend beyond second phase, marked by vegetative multiplication of the simple ray, tly attached to the arch itself. The lepidosiren offers the simplest con- 1 of such 'diverging appendage' in the single slender bony piece con- ed with the element 40*. Cuvier and other ichthyologists cite a series iges of this kind of development of the hyoidean appendage from a si- simple beginning up to a 30-fold repetition of the single ray (*Elops*); the 'branchiostegal' rays have been found in much greater numbers in in fossil fishes. Like the 'pectoral' rays, they support a duplicature of brane, which plays freely backwards and forwards, reacting upon the ent medium, and forming, in short, a cephalic fin, but with its powers stricted and adjusted, as to propel the water through the branchial cham- of the fish, instead of driving the fish through the water; in which latter on, indeed, the occipital appendages (pectoral fins) in most osseous fishes and do perform but a very small share.

we next proceed to compare the frontal segment, N III and H III, dis- bered as above described from the parietal vertebra, and, by the separa- of the sutures, from the bones terminating the skull anteriorly, we shall a neural arch (fig. 3) closely repeating the characters of that of the oc- al vertebra. The *centrum* is sometimes represented simply by the forward nsion of ossification of the basisphenoid (11), which I regard as the ho- ype of the ossification of the capsule of the notochord beneath the cen- is of the anterior trunk-vertebræ in the silurus; sometimes, also, of a di- :t superincumbent symmetrical ossicle (9′, fig. 5), answering to the rudi- tal (central part of the) body of the atlas supported by the inferior bony ;, in the silurus. This more complex condition of the centrum of the frontal ebra is well-seen in the sword-fish. The bones 10, 10, which directly rest 19′, when it exists, which defend the sides of the prosencephalon, and :h are either grooved by the optic nerves, or have those nerves perforating fibro-cartilaginous membrane close to the margin of the bone (10) from :h it is continued, are obviously the *neurapophyses*. They are, however, ll; inasmuch as the segment of the brain to which they relate is of inferior in bony fishes: and they are still smaller in comparison with the spine which is enormously expanded, in relation to its accessory functions as chief contributor to and protector of the orbits. The bones 12, wedged veen the neurapophyses and spine, affording an articular surface to the ximal piece of the hæmal arch, and developing a transverse process for cular attachments, are the *parapophyses*. The bones (17) have as little ntial connection with the typical neural arch above demonstrated, as the es 16, 16″ had with the corresponding arch of the parietal vertebra: and r more peculiar form in relation to the ball which they protect, and their able histological condition in the vertebrate series, have not only prevented r ever being mistaken for parts of cranial vertebræ, but have led to the osite extreme of excluding them altogether from the bones of the skull, h which they are as much entitled to rank as the petrosal (16) or the oinal (19); but always in the category of sense-capsules or 'splanchno- letal' pieces.

n regard to the inferior arch of the frontal segment, the subdivision of its stituent elements, in subserviency to its special functions, is carried to as at an extent as in that of the parietal segment. I regard the four over- oing and closely-connected pieces from the upper joint (28*a*) to the lower

* Hunterian Lectures on Vertebrata, p. 79, fig. 27, 37.

joint (28*d*) inclusive, as the *pleurapophysis*: it is not so obvious w the bones 29–32 form a subdivided *hæmapophysis*, or whether the te bone (32), forming by symphysis with its fellow the crown of the inverte may not be the moiety of a mesially divided *hæmal spine*. But the g character of the inverted arch (H III), as the hæmal complement of th tal vertebra is unmistakeable, and its serial homology with the succ arches (H II and H I) is fully illustrated in fishes by its supporting *div appendages* (34–37). These, in the series of fishes, manifest, in as permanent arrests, the chief phases of development that the correspo appendages of the occipito-hæmal arch have been described to pass thr The diverging appendage of the fronto-hæmal arch is a single and s bony style in the lepidosiren; it consists of three or four simple rays monk-fish and some other plagiostomes; it has one ray expanded into a proximal piece in the conger, which sustains a distal segment of the appen one member of which, the 'subopercular,' still retains the long and sle ray-like form, which is, also, clearly traceable in the broader but lon curved 'opercular'; in the cod, as in most osseous fishes, the parts o second segment of the appendage (35, 36, 37, fig. 5) are metamorphosed the proximal one (34), into broad and flat bones. The fin-like fold of gument, sustained and moved by means of this diverging appendage a muscles, reacts upon the surrounding water; but, like the hyoid-fins, which the tympanic or opercular fins are closely connected, they are cl subservient to the creation of the respiratory currents and their dire through the gill-chambers. The weight of these appendages, and the stant movements in connection with respiration, as well as those whic hæmapophysial portions of the arch, modified in subserviency to nutr have to perform, as jaws, explain the necessity of the subdivision of the porting pedicle into overlapping pieces allowing of a certain elastic yiel with recoil, and thus diminishing the liability to fracture without affec except by increasing, the strength of the arch. The trochlear joint betw the two elements of this arch (at 28*d* and 29) with its cartilage and syn sae, repeats the complex structure of the articulation between the verte and sternal portions of the ribs in birds. To the fore-part of the lower p (28*d*) of the pleurapophysis is usually articulated a bone (24) connecti with another bone (20) in advance: the ground for regarding 24 as appert ing to the arch (20, 21 and 22, H IV) will be explained in the descriptio that arch.

There remains, then, in the fish's skull, to be considered, the grou bones (N IV, H IV, fig. 5) forming its anterior extremity; and we have to quire, whether there can be traced in this easily separable group such a c cordance in its formation with the arrangement of the constituents of foregoing segments as will justify its being regarded as a natural segmen the skull, and as still illustrating the type on which all the other segment the endoskeleton have been constructed. Fig. 4 gives the same view of bones of this group in vertebral relation with the rhinencephala as the vi in figs. 1, 2 and 3 do of the bones having a similar relation to the three lar segments of the brain: we perceive the single and symmetrical bone (forming the basis of the arch, and sustaining the bones 14, 14, which m immediately support the olfactory ganglions and transmit their nerves, eit by grooves or foramina, to the olfactory capsules: the key of the arch formed by the single and symmetrical bone 15, which is articulated to a chiefly sustained by the bones 14, 14: but 15 is expanded and deflec anteriorly so as to rest directly upon 13 and completely obliterate the neu canal; the hæmal canal being in like manner closed by the approximation hæmal spine (22) to the nasal centrum (13), and by the upward develop- . of the processes of 22 which join the neural spine (15). Much modifi- n was to be expected in the segment which terminates the skeleton ·iorly; and yet the typical characters of the neural arch are more com- ly preserved here than at the opposite end of the vertebral column. If bones 4, 8, 12, which I recognise as 'parapophyses' in the cranial ents I, II, III, must be viewed as superadded intercalations for the al and characteristic expansion of the neural arches of those segments— al elements, indeed, of the typical vertebra, but with modified connections ranial functions—then the disappearance of their homotypes in the nasal ent restores its neural arch (fig. 4) to the more common condition, and we nise in 13 the *centrum*, in 14, 14, the *neurapophyses*, and in 15 the *neural* of the nasal vertebra.

t the segment to be complete should exhibit a second arch, inverted; and nd such arch closed or completed by the symphysis of the bones 22, ., and suspended to the sides of the centrum 13 and to the neurapophyses . by the bones 20, as the piers or crura of the arch; these bones being ected to the key-bones 22, by the intermediate bones 21. Now, the fications which these elements of the inverted or hæmal arch of the vertebra have undergone, are, also, much less than might have been ipated from the extent to which the segments are modified at the oppo- extreme of the endoskeleton. All the normal elements of the hæmal for example, are retained: 20 is the *pleurapophysis*, 21 the *hæmapo- s*, and 22 the *hæmal spine*, in most fishes divided at the middle line, but times confluent with its fellow *e. g. Diodon*. The essential (pleur- hysial) part of 20 extends in many fishes (*e. g.* percoids) like a short ht rib from its articulation with 13 and 14 to the condyle at its opposite o which the hæmapophysis 20 is articulated; but it usually, also, de- es a process from its hinder margin downwards and backwards, which attachment to the diverging appendage of the arch H IV. The de- ment of the other bones of the arch, 21 and 22, outwards, downwards backwards, is still more marked in relation to the protractile and retrac- movements of the arch in most osseous fishes; and some anatomists, enced by the form and proportions rather than the connections of those , have described them as independent parallel arches: but, as such, must be regarded as being suspended by their apices or key-stones to xis of the skull, and as having their haunches hanging freely downwards outwards—a position the reverse of that of the foregoing inferior arches e skull and of every typical hæmal arch. The reduction of that di- nt development, characteristic of the bones 21 and 22 in fishes, is ef- l in a great degree within the limits of the piscine class: already we one of the spurious arches abrogated in the salmonoid fishes by the short- of 22, and its more direct continuation from 21, which now forms the r part of the upper border of the mouth and supports teeth: the con- : maxillaries and premaxillaries send down only a single divergent ss from their point of suspension to the palatine condyle in the plecto- nic fishes; and the consolidation of all the elements of the palato-maxillary into its normal unity is effected in the lepidosiren*. The palatines (20) rs form the true bases or suspensory piers of the inverted hæmal arch eir points of attachment to the prefrontals (14); the premaxillaries, 22, itute the true apex or crown at their symphysis or point of confluence, ; the approximation of which to the anterior end of the axis of the skull ndered possible, in fishes, by the absence of any air-passage or nasal

* Hunterian Lectures, Vertebrata, p. 81, fig. 29.

canal. The diverging appendage, sometimes single and anchylosed arch (lepidosiren); sometimes single and detached like a long, narrov (some murænoids); more commonly consists of two bones (23, 24), extend outwards, downwards, and backwards from the pleurapophysi but the more constant and better ossified bone of the two, no. 24, artic posteriorly with the succeeding pleurapophysis (28) and combines its ments with those of its own arch, just as the diverging appendages thoracic hæmal arch in the bird associate the movements of that arc those of the next in succession (as in fig. 15, *pl*, *a*, *pl*). The hæmapo here, as at the opposite end of the body, begin so far to dissociate them from the pleurapophyses as to articulate also directly with the centru as well as with the pleurapophyses. I regard this as a very interestin proximation to that condition of the typical vertebra which is illustrat the diagram (fig. 14), and which is seen in nature in the caudal vertel the crocodiles, enaliosaurs and menopome (fig. 28, H).

From the foregoing analysis it appears, then, that in osseous fish endoskeletal bones of the head are arranged, like those of the trunk, i ments; that these are four in number, and that they closely conform character of the typical vertebra.

Thus we have four centrums and neural arches: viz.

N I. Epencephalic arch (figs. 1 and 5, 1, 2, 3, 4);
N II. Mesencephalic arch (figs. 2 and 5, 5, 6, 7, 8);
N III. Prosencephalic arch (figs. 3 and 5, 9, 10, 11, 12);
N IV. Rhinencephalic arch (figs. 4 and 5, 13, 14, 15).

As a collective name for the sum of these immoveably articulated a would be as convenient as the anatomist finds the names 'sacrum' and pace,' applied to similarly consolidated portions of vertebral segments pelvic and abdominal regions of certain air-breathing vertebrates, tl 'cranium' may well be retained for the neural arches of the skull: should be understood to signify, in all animals, the bones 1 to 15 incl whereas it has, hitherto, been applied variably in different species; times including sense-capsules and facial bones, intercalated to expan walls of the cavity for a large brain; and more frequently excluding cranial bones, those of the rhinencephalic arch, for example, which enco as essential a part of the encephalic chamber, as the sacral vertebræ do neural canal at the opposite end of the vertebral axis; although in bot stances the extremities of the neural axis may have been withdrawn, i course of its concentrative change and movement, from their original s

The hæmal arches indicated by the arrows in fig. 5, the heads ma the point of junction or crown, are,—

H I. Scapular arch (50–52);
H II. Hyoidean arch (38–43);
H III. Mandibular arch (28–32);
H IV. Maxillary arch (20–22).

The diverging appendages of the hæmal arches are,—

1. The Pectoral (54–57);
2. The Branchiostegal (44);
3. The Opercular (34–37);
4. The Pterygoid (23–24).

The bones or parts of the splanchno-skeleton which are intercalated or attached to the arches of the true vertebral segments, are,—

The Petrosal (16) or ear-capsule, with the otolites, 16″;
The Sclerotal (17) or eye-capsule;
The Turbinal (19) or nose-capsule;
The Branchial arches,

The Teeth.

he bones of the dermo-skeleton are,—

The Supratemporals;

The Supraorbitals;

The Suborbitals;

The Labials.

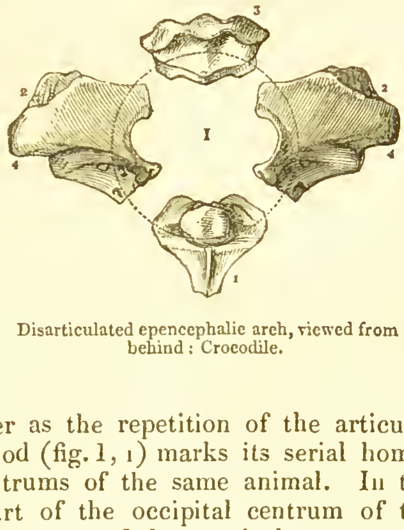
ich appears to be the natural classification of the parts which constitute complex skull of osseous fishes.

s the object of the present work relates chiefly to the endoskeleton, I only added the osseous parts of the sense-capsules to the cranial vertebræ r. 5; omitting the branchial arches and dermal bones: the hæmal arches their appendages are given in diagrammatic outline.

eptiles.—In proceeding with the inquiry into the natural arrangement of skull-bones, I have selected from the *Reptilia* the crocodile, as a typical nple of that class, and one most likely to facilitate the inquiry on account ie characteristic persistence of the primitive cranial sutures.

ursuing the same mode of investigation as in the case of the fish, let us ticulate the hindmost segment of kull and so detach the four bones, esented in fig. 18. The dotted e indicates the points at which e bones are joined together, in r to encompass the epencephalon, iindmost segment of the brain. ı is the *centrum*; 2, 2 are the *neur-hyses* with the coalesced *par-hyses* (4, 4); and 3 is the *neural e.* This element differs but little ize and shape from the similarly ched and depressed neural spine he atlas of the crocodile. The le convex condyle at the back part o. 1 makes that centrum resemble posteriorly convex bodies of the

Fig. 18.



Disarticulated epencephalic arch, viewed from behind: Crocodile.

k-vertebræ in as striking a manner as the repetition of the articular avity in the basioccipital of the cod (fig. 1, 1) marks its serial homo- with the succeeding vertebral centrums of the same animal. In the ending process from the under part of the occipital centrum of the odile (fig. 18, 1), we see a second character of the cervical centrums in reptile repeated, viz. their inferior exogenous spine. The neurapo-ses (2, 2), like those of the atlas, meet above the neural canal: they give to the vagal and hypoglossal nerves, and protect the sides of the me-a oblongata and cerebellum. The neural spine (3) protects the upper ace of the cerebellum: it is also traversed by tympanic cells, and assists, 1 the bones 2, 2, in the formation of the chamber for the internal ear. special homology of the outstanding processes (4, 4) in the crocodile serpent (fig. 10), with the similarly situated but distinct 'paroccipital' es in the cod, is confirmed by their resuming their independency in the ler segment of the skull of the chelonian reptiles; and the occipital neural 1 of the crocodile is reduced by their confluence with the neurapophyses he condition of those of the trunk-vertebræ, as composed, viz. of four ead of six elements.

he epencephalic arch offers the same simple condition not only in the idians but in most saurians: the chameleons however retain, like the chelonians, the ichthyic independence of the parapophyses (4, 4). In ba chians the epencephalic arch is reduced to the two important elements, neurapophyses; which meet and join each other below as well as above foramen magnum, and develope the exogenous zygapophyses, or two occi condyles, for articulation with the corresponding processes of the neural of the atlas. The basioccipital, if it exists in batrachians, is rudimental confluent with the basisphenoid, and the supraoccipital is in like ma recognisable only as the posterior border of the backwardly produced pari The parapophyses are short exogenous processes of the neurapophyses of much simplified epencephalic arch in all batrachian reptiles.

The chief modification that distinguishes the above-described segme the crocodile's skull from its homologue in the fish, is the absence o attached inverted or hæmal arch. We recognise, indeed, the special ho logues of the piscine constituents of that arch in 50, 51 and 52, fig. 22. upper suprascapular piece (50) is however free, disconnected from any ment, and retains, in connection with the loss of its proximal or cra articulations, its cartilaginous state: the scapula (51) is ossified, as is like the coracoid (52), the lower end of which is separated from its fellow by interposition of a median, symmetrical, partially ossified piece called 'epis num' (*hs*). The power of recognising the special homologies of 50, 51, 52 in the crocodile, with the similarly numbered constituents of the arch in fishes (fig. 5), though masked not only by modifications of form and portion but even of very substance, as in the case of 50, depends upon circumstance of these bones constituting the same essential element of archetypal skeleton: for although in the present instance there is superad to the adaptive modifications above-cited the rarer one of altered connecti Cuvier does not hesitate to give the same names (suprascapulaire) t and (scapulaire) to 51, in both fish and crocodile: but he did not perceiv admit that the narrower relations of special homology were a result of, necessarily included in, the wider law of general homology. According the view of this law here taken, we discern in 50 and 51, fig. 22, a teleologic compound *pleurapophysis*, in 52 a *hæmapophysis*, and in *hs* the *hæ spine*, completing the hæmal arch.

The general relations of the scapulo-coracoid arch to a hæmal or co one have been long recognised, but the vertebral segment to which it ap tains seems not hitherto to have been suspected, and has certainly not b satisfactorily determined. Oken, who had observed the free cervical rib a specimen of the *Lacerta apoda*, Pallas (*Pseudopus*), deemed them re sentatives of the scapula, and this bone to be, in other animals, the coales homologues of the cervical pleurapophyses*. In no animal are the conditi for testing this question so favourable and obvious as in the crocodile: only do cervical ribs coexist with the scapulo-coracoid arch, but they ar unusual length and are developed from the atlas as well as from each s ceeding cervical vertebra: we can also trace them beyond the thorax to sacrum, and throughout a great part of the caudal region, as the sutures the apparently long transverse processes of the coccygeal vertebræ dem strate in the young animal; the lumbar pleurapophyses being manifes at the same period as cartilaginous appendages to the ends of the long d pophyses.

* "Auch die Scapula nicht *ein* Knochen, sondern wenigstens eine aus fünf Halsrip zusammengeflossene Platte ist."—Programm, &c., 4to, 1807, p. 16. He reproduces same idea of the general homology of the scapula in the 'Lehrbuch der Natur-philosop 1843, p. 331, ¶ 2381. Carus also regards the scapulo-coracoid arch as the reunion of se ral (at least three) protovertebral arches of the trunk-segments. 'Urtheilen des Knoc und Schalen gerustes, fol. DXLIII.

'he scapulo-coracoid arch, both elements of which retain the form of ng and thick vertebral and sternal ribs in the crocodile, is applied in the eton of that animal over the anterior thoracic hæmal arches. Viewed more robust hæmal arch, it is obviously out of place in reference to the of its vertebral segment. If we seek to determine that segment by the le in which we restore to their centrums the less displaced neural arches he sacrum of the bird (fig. 27, *n* 1–*n* 4), we proceed to examine the verte- before and behind the displaced arch with the view to discover the one ch needs it in order to be made typically complete. Finding no centrum and ral arch without its pleurapophyses from the scapula to the pelvis, we give our search in that direction ; and in the opposite direction we find no verte- without its ribs until we reach the occiput: there we have centrum and ral arch, with coalesced parapophyses—the elements answering to those uded in the arch N I, fig. 5—but without the arch H I ; which arch only be supplied, without destroying the typical completeness of antece- t cranial segments, by a restoration of the bones 50–52, to the place which naturally occupy in the skeleton of the fish. And since anatomists generally agreed to regard the bones 50–52 in the crocodile (fig. 22) specially homologous with those so numbered in the fish (fig. 5), we st conclude that they are likewise homologous in a higher sense ; that in 5 the scapulo-coracoid arch is in its natural or typical place, whereas in crocodile it has been displaced for a special purpose. Thus, agreeably a general principle, we perceive that as the lower vertebrate animal strates the closer adhesion to the archetype by the natural articulation of scapulo-coracoid arch to the occiput, so the higher vertebrate manifests superior influence of the antagonising power of adaptive modification by removal of that arch from its proper segment.

The scapula retains the more common cylindrical long and slender rib- form of the pleurapophysis in the chelonian reptiles, where, from the ater length of the neck, it has retrograded further than in the crocodile n its proper centrum, and is placed not upon, but within, an anterior racic hæmal arch, the pleurapophysis of which has, on the other hand, n expanded like a scapula.

f the arguments founded upon the relations of the scapulo-coracoid arch he segments of the skeleton in osseous fishes and crocodilians be admitted ustain the conclusion here drawn from them, that arch must be held to n the hæmal complement of the occipital vertebra in all animals. Bojanus, llustrating his vertebral theory of the skull by the osteology of the *Emys ropæa*, thus defines the

"VERTEBRA OCCIPITALIS, SIVE CAPITIS PRIMA.

Basis occipitis, seu *corpus* hujus vertebræ,
Pars lateralis occipitis, sive *arcus*,
Crista occipitalis, *processus spinosi* loco,
Cornu majus hyoidis, *costæ vertebræ* occipitalis comparandum *."

He adds a dotted outline of the hyoid arch to complete the *vertebra oc- italis*, in tab. xii. fig. 32, B. 1 of his beautiful Monograph.

Supposing the special homology of the middle cornua of the hyoid of the lonian, so represented and compared to ribs by Bojanus, with the stylo-, - and cerato-hyals of the fish (fig. 5, 38, 39, 40) to have been correct, which metamorphoses of the hyoid and branchial arches in the batrachians dis- ve, the singular and highly interesting change of position as well as shape the true ceratohyals, during the same metamorphosis, prepares us to expect etrogradation of the hyoid arch in respect to its proper centrum, in the

* Anatome Testudinis Europææ, fol. 1819, p. 44.

skulls of the air-breathing vertebrates. In the young tadpole the thick tilaginous hyoidean arch * is suspended, as in fishes, from the tympanic pedi the slender hyoidean arch of the mature frog is suspended from the petr capsule †. The mandibular arch has, also, receded; and the scapular a which, at its first appearance, was in close connection with the occiput, furt retrogrades in the progress of the metamorphosis to the place where we it in the skeleton of the adult frog.

The argument, therefore, may be summed up as follows. The positio the neurapophyses in the dorsal vertebræ of chelonians and in the sacral tebræ of dinosaurians and birds, shows that a change of relative positio respect of other elements of the same vertebra may be one of the teleolog modifications to which even the most constant and important elements subject. Instead of viewing such shifted arches as independent individual pa we trace their relation to the stationary elements of the vertebral segment the centrums. Thus, commencing, for example, with the anterior of sacral vertebræ of the ostrich, A in fig. 27, we observe that, besides s porting its own neural arch, it bears a small portion of that of the next v tebra: the third neural arch (n 1) has encroached further upon the centr of the vertebra in advance; and thus, in respect to the neural arch (n 2 it were viewed with the centrums, c 2 and c 1, upon which it equally re apart from the rest of the sacrum, it would appear to appertain equally either, and be referable to the one in preference to the other quite g tuitously. Nevertheless n 2 is proved, by the intermediate changes in an cedent neural arches, to belong actually, and in no merely imaginary or tra cendental sense, to c 2 altogether, and not to the segment of which c 1 is centrum; and in tracing the modifications of those sacral vertebræ wh follow c 2, we find n 4 to have regained nearly the whole of its centrum, and the normal relations of the elements are quite restored in the succeed vertebra.

Now let us suppose the habits of the species to have required a m extensive displacement of the arch (n 2) and its appendages: if its forn characters as a neural arch were still retained beneath the adaptive devel ment superadded to the adaptive dislocation, and if the segments before a behind the centrum c 2 were found complete, and that centrum alone wanti its neural arch; would the mere degree of modification in respect of relat position nullify the conclusion that the shifted arch appertained to such complete segment, and forbid that restoration to the typical condition, wh no anatomist, it is presumed, will dispute in the case of n 2, c 2, fig. 27 ? anthropotomist hesitates in pronouncing the exact vertebra to which t sixth ribs belong in the human skeleton. But, separate that costal ar with the two bodies and neural arches of the vertebræ with which it artic lates, and to which of them it belonged would be as questionable as in t instance of the displaced neural arch in the bird's sacrum. The head of ea rib is applied half to the upper centrum, half to the lower one: the upp border of the neck of the rib articulates with the upper neural arch, the t bercle with the diapophysis of the lower neural arch. If a naturalist, n conversant with the definitions of human anatomy, were shown this detach part of the human skeleton and were pressed to determine the proper centr and neural arch of the hypothetically displaced costal element, the attem might seem to him gratuitous: and to the question, to which of su centrums the rib exclusively (as to the pre-existing pattern) belonged?

* Cuvier, Ossem. Foss. v. pt. ii. pl. 24, fig. 23, *a*.

† *Ib.* fig. 27, *a*:—an intermediate stage is shown at fig. 25. Dugés and Reichert confi and further illustrate this change of position of the hyoidean arch.

at reply, to neither. And such, doubtless, would be the matter-of-fact ver most congenial to the character of mind which would limit its views le specialities of the ribs as parts independent of any ideal archetype, or nable or unwilling to push the consideration of their connections beyond purposes apparently subserved thereby. A second anatomist might see le more constant articulation of the costal tubercle with the transverse ess, a character which would incline the balance in favour of the vertebra hich the transverse process belonged. A third anatomist might extend comparisons to other ribs and centrums, and finding the lower centrum ining by degrees a greater proportion of the head of the rib, until the and last ribs respectively wholly articulated to the centrum answering to lower one in the case of the hypothetically detached sixth pair, he would clude that such pair of ribs belonged essentially to the lower and not he upper supporting centrum, and he would count accordingly such er centrum with its neural arch, as the sixth of those vertebræ which are racterized as supporting ribs. The anthropotomist, in fact, in so counting defining the dorsal vertebræ and ribs, admits unconsciously perhaps, an ortant principle in general homology, which pursued to its legitimate sequences and further applied, demonstrates that the scapula is the modi- rib of that centrum and neural arch which he calls the 'occipital bone,' that the change of place which chiefly masks that relation (for a very nentary acquaintance with comparative anatomy shows how little mere 1 and proportion affect the homological characters of bones) differs only xtent and not in kind from the modification which makes a minor amount omparative observation requisite in order to determine the relation of the ted sixth rib to its proper centrum.

Vith reference, therefore, to the occipital vertebra of the crocodile, if the nparatively well-developed and permanently distinct ribs of all the cervical ebræ prove the scapular arch to belong to none of those segments, and, be wanting to complete the occipital segment, which it actually does nplete in fishes, then the same conclusion must apply to the same arch in er animals, and we must regard the occipital vertebra of the tortoise as npleted below by its scapulo-coracoid arch, and, not as Bojanus supposed, its hyoidean arch*.

Vith these views of the general homology of the scapulo-coracoid arch, embryologist will observe with less surprise its constant appearance in first instance close to the occiput, and its equally constant primitive ver- l position; however far back it may be subsequently removed, or to atever extent it may be rotated, in the same progress to maturity, out of original parallel direction with the more normal pleurapophyses.

Returning to the study of the crocodile's skull in reference to the verte- te archetype, if we proceed to dislocate the next segment in advance of occipital, we bring away in connection with the long base-bone, 5 and 9, 22, the bones connected by the double lines N II, N III, and by the

Geoffroy St. Hilaire selected the opercular and subopercular bones to form the inverted of his seventh (occipital) cranial vertebra (Table III. and note 11), and took no account he instructive natural connections and relative position of the hyoidean and scapular es in fishes. With regard to the scapular arch, he alludes to its articulation with the ll in the lowest of the vertebrate classes as an 'amalgame inattendue' (Anatomie Philo- hique, p. 481); and elsewhere describes it as a "disposition véritablement très singulière, ue le manque absolu de cou et une combinaison des pièces du sternum avec celles de la pouvoient seules rendre possible."—Annales du Muséum, ix. p. 361. A due appre- ion of the law of vegetative uniformity or repetition, and of the ratio of its prevalence power to the grade of organization of the species, might have enabled him to discern true signification of the connection of the scapular arch in fishes.

curved arrows H II and H III. The relations of the superior series of b as neural arches to the optic lobes and cerebrum are even less doubtful in many fishes, by reason of the much smaller degree of independent o cation of the proper capsule of the acoustic labyrinth. Taking, then bones forming the arch N II, we find them, viewed from behind, to pr the general arrangement shown in fig. 19. The hinder (basisphenoidal) portion of the bone 5 and 9 forms the *centrum*, and immediately supports the floor of the mesencephalon, or lobe of the third ventricle, being excavated for the pituitary prolongation of that cavity: it also sends a process downwards, repeating, like the basioccipital, the inferior exogenous spine of the centrums of the cervical vertebræ. The bones 6, 6 protecting the sides of the mesencephalon, and notched for the transmission of the trigeminal nerve, manifest the *neurapophysial* characters of the segment. As accessory functions they contribute, like the corresponding bones in fishes, to the for tion of the ear-chamber. They have, however, a little retrograded in p tion (see fig. 9), resting below, in part, upon the occipital centrum, and s porting more of the spine of that centrum (3) than of their own (7); wl is, however, formed of a single bone, and in so far manifests more of normal character of the element completing the neural arch, as its crowr key-bone, than does the homologous divided and often divaricated bon fishes. This and other analogous facts show that although the lowest tebrate class adheres most, as a whole, to the archetype, yet that it can recognised clearly and unequivocally only by patient study of its modif tions in all classes: for even the lowest have special exigencies arising of their sphere of existence calling for modifications of the type which not present in other and higher classes. We shall find, indeed, that the c nation of the basi- and pre-sphenoids ceases in mammals, and that they c coalesce in that class, being primitively distinct; so that the second cra centrum (5) may be removed with its neural arch, in the fœtal quadru (fig. 24) or human subject (25), without doing violence to nature by the of the saw. The bones 8, 8, fig. 19, wedged between 6 and 7, here, also, nifest more of their *parapophysial* character than in fishes, inasmuch as t are excluded from the inner walls of the cranium, whilst they retain manifest broadly their characters as outstanding processes for muscular tachment. But, besides affording ligamentous attachment to the hyoid a (39, 40), they articulate largely with the proximal element (18) of the m dibular arch, whose backward displacement, in comparison with its m normal position in the fish's skull (fig. 5), is as clearly illustrated in the m morphosis of the anourous batrachia, as is that of the hyoidean or scap arches.

Fig. 19.

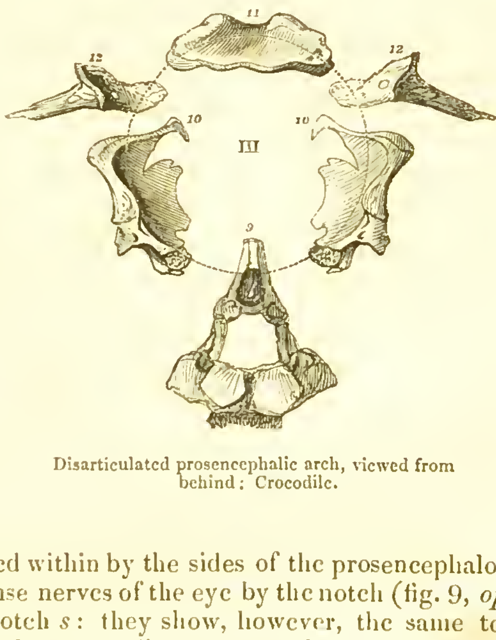
Disarticulated mesencephalic arch, viewed from bel Crocodile.

Referring, then, to the side view of the cranial vertebræ of the crocod (fig. 22), we see the hæmal arch of the second or parietal vertebra in hyoid (39, 40, 41) retaining so much of its embryonic dimensions as is requi ts restricted functions, and having no call for progressive growth in subiency to a branchial respiration. It consists of a ligamentous stylohyal, *leurapophysis*, retaining the same primitive histological condition which ructs the ordinary recognition of the same elements of the lumbar hæmal ies. The hæmopophyses and hæmal spine are, however, here as there, e advanced in respect of their tissue. The *hæmapophysis* is ossified like so-called 'abdominal ribs,' and usually, like them, consists of two portions, ing the special names of epihyal (39) and ceratohyal (40): the *hæmal e* (41) retains its cartilaginous state like its homotypes in the abdomen: e they get the special name of 'linea alba' or abdominal sternum, here basihyal.' With respect to formal modification, this element is chiefly arkable in the crocodile for its broad expanse: it sustains the ascending ular ridge at the base of the tongue, which, applying itself against the cending 'palatum molle,' constitutes an effectual barrier against the entry vater into the glottis from the mouth, whilst the crocodile is engaged in rcoming the struggles of a submerged and drowning prey.

There being no need of diverging appendages from the hyoidean arch in crocodile, branchiostegal rays are not developed. The scapular arch is ilarly simplified in *Anguis* and other serpentiform lizards; but, to those) recognise its true homology, its presence without a trace of its appenes, the fore-limbs, will create no more surprise, than the presence of the idean arch without the branchiostegal fins or of the mandibular arch without opercular fins.

On removing the neural arch of the parietal vertebra, with or without the tion of the connate centrum (5), the bones completing, with the part (9), corresponding arch of the frontal vertebra present the general arrangent shown in fig. 20.

Fig. 20.



Disarticulated prosencephalic arch, viewed from behind: Crocodile.

The compressed produced ie, 9, shown in natural contion with the bone 10 in 9, notwithstanding its moed form, presents all the ential characters of the *cenm* of the arch: although it y have been developed exsively from the capsule of notochord, like the coaced inferior parts of the ceral centrums in the silurus: re is no distinct ossicle anering to the central part of centrum of the frontal vera, like 9′, fig. 5, in certain ny fishes. On the other hand, find the *neurapophysial* chaters of the orbito-sphenoids , 10) more largely and typilly manifested in the crocoe: they are smoothly excavated within by the sides of the prosencephalon: y dismiss the great special-sense nerves of the eye by the notch (fig. 9, *op*), d the motor nerves by the notch *s*: they show, however, the same tenncy to change of position as the succeeding neurapophyses; for though ey support a greater proportion of their proper spine (11), they also suprt part of the succeeding spine (7), and rest below in part upon the parietal centrum (5). The *neural spine* of the frontal vertebra (11) retains normal character as a single symmetrical bone, like the parietal spine, wh it partly overlaps. It is much developed longitudinally, but more in anterior, and less in the lateral direction than in most fishes.

One cannot contemplate the relative position of the frontal to the pari and of the parietal to the supraoccipital, which is overlapped by the pari and itself overlaps the flattened spine of the atlas, without a conviction of serial homology of these single, median, imbricated bones, all complet arches above the neural axis, and each permanently distinct from the pi or haunches of the arch of which it forms the key-stone. In like man the serial homology of those piers or neurapophyses, viz. the laminæ the atlas, the exoccipitals, the alisphenoids and the orbitosphenoids, is equa unmistakeable. Nor can we close our eyes to the same serial relations of the postfrontals (fig. 20, 12, 12) as parapophyses of their vertebra, w the mastoids (8) and the coalesced paroccipitals (4). The frontal *para physis*, 12, is wedged between the back part of the spine, 11, and the ne apophysis, 10: its outward process extends backwards and joins the n parapophysis (8); but, notwithstanding the retrogradation of the man bular arch, it still receives a small part of its own *pleurapophysial* elem (28). This element now manifests its typical unity: vegetative subdivisi much reduced in the batrachian reptiles, no more prevails in the devel ment of the frontal pleurapophysis in any higher vertebrate. The serpe exhibit this element under the common form of a rib; longer, indeed, th are any of the pleurapophyses in the batrachian order; but it has so retreated in serpents as to be exclusively attached to the parietal para physis, which is remarkably elongated and produced backwards, and s pends the long, slender, straight and simple frontal pleurapophysis (tympa pedicle) vertically from its posterior extremity. In lacertians no. 28 is v tically suspended from no. 8, and, commonly also, from no. 27, which is c tinued from the backwardly produced parapophysis of the frontal vertel (12) to that of the parietal vertebra (8) in most of this division of the C vierian order *Sauria*. In chelonians and crocodilians the diverging appe dage of the maxillary arch (27) descends and applies itself to a large prop tion of no. 28, down to its lower articular end, and contributes to fix a strengthen that bone, as well as the modified costal arch from which it verges.

The condition of the shortening, expansion and fixation of the fron pleurapophysis in crocodiles and chelonians is exemplified in the uses which the modified hæmapophyses, completing that costal arch, are p Tortoises crop the grass by the application of the trenchant horny plates the under to those of the upper jaw: turtles equally need a fixed suspenso joint of the under jaw in the act of biting and dividing the tough sea-wee Crocodiles have the frontal hæmapophyses (mandibular rami) unusual long; supporting numerous large laniary teeth, and requiring a fixed a firm point of suspension in the violent actions to which they are put in r taining, and overcoming the struggles of their prey.

The teleological complication of the lower or distal elements of the ar in question (29–32, fig. 22) is carried further than in fishes: there was mo need, in fact, for a combination of the greatest elasticity and strength wi the least weight of bone* in the frontal hæmapophysis of the crocodile th in the frontal pleurapophysis of the fish (28 *a*–28 *d*, fig. 5).

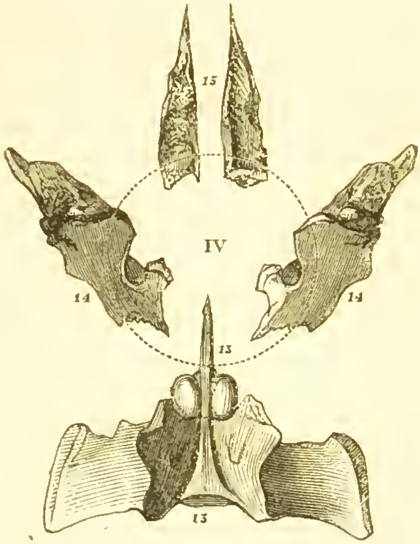
There, lastly, remain then in the skull of the crocodile the bones inte

* Conybeare, Geol. Trans. 1821, p. 565. Buckland, Bridgewater Treatise, 1836, vol. p. 176. This author well illustrates the final purpose of the subdivision of the mandibul

ed by the lines N IV and the arrow H IV, with those numbered 26, 27, 73, and we have to inquire whether through all the modifications which r extreme position subjects them to, we can still trace any evidence of their ngement according to the vertebrate type.

long and slender symmetrical grooved bone, like the ossified inferior of the capsule of a notochord, is continued forwards from the centrum ie foregoing vertebra, and stands in the relation of a *centrum* (13) to the ical plates of the bones 14, which expand as they rise into the broad and k triangular plates with an ex-d horizontal superior surface. arch of which these form the s, and to the anterior rhinen-ialic prolongations traversing ch arch they stand in the re-on of *neurapophyses*, is com-ed by the two bones (15): which herefore, regard as a divided ral spine. In fishes we have that the corresponding ele-nt of the parietal vertebra was larly divided, whilst the neural e of the nasal vertebra was le: in the crocodile the re-se conditions prevail. In a spe-of alligator I have observed bone 13 continued further for-d, expanded, and divided at the dle line, the two divisions form-a small disc on the bony palate. e centrum of the nasal vertebra ivided longitudinally at the me-n line in batrachians, ophidians, l most lacertians; it is single in lonians, but retains its carti-inous state in some species (*Emys expansa, e.g.*). The neurapophyses 14) transmit the olfactory nerves in all reptiles; but the ganglions are ally withdrawn backwards into the prosencephalic neural arch, leaving

Fig. 21.



Disarticulated rhinencephalic arch, with the anchylosed pterygoids (24) viewed from behind: Crocodile.

ns in the recent and extinct saurians by pointing out the similarity of the structure to adopted in binding together several parallel plates of elastic wood, or steel, to make a s-bow; and also in setting together thin plates of steel in the springs of carriages. Dr. kland adds, "Those who have witnessed the shock given to the head of a crocodile by act of snapping together its thin long jaws, must have seen how liable to fracture the er jaw would be, were it composed of one bone only on each side."—*Ib.* p. 177. The e reasoning applies to the composite condition of the long tympanic pedicle in fishes. each case the splicing and bracing together of thin flat bones of unequal length and of ing thickness affords compensation for the weakness and risk of fracture that would other-e have attended the elongation of the snout. In the abdomen of the crocodile and plesi-ur the analogous composition of the hæmapophyses (abdominal ribs) allows of a slight nge of length in the expansion and contraction of the walls of that cavity: and since phibious reptiles, when on land, rest the whole weight of the abdomen directly upon the und, the necessity of the modification for diminishing liability to fracture further appears. what we are here chiefly concerned in is the evidence that the general homology of nentary parts of a natural segment is not affected by the modification of teleological nposition of such parts. What happens to the hæmapophysial or inferior elements of inverted arch in the abdominal segments of the crocodile also affects the same elements cranial hæmal arch; and the subdivision of the pleurapophyses of the trunk in the rgeon is repeated in the same elements of the cranial vertebræ in osseous fishes.

only the nerve-trunks to be protected by the nasal neurapophyses. Tl are, therefore, more approximated, and the anterior termination of the ne canal is much contracted; and, in the tailless batrachia, the nasal n apophyses coalesce together.

We recognise in that element (20) of the fourth or foremost inverted a of the crocodile's skull, which is in connection with the body (vomer, 13) descending plates of the neurapophyses (prefrontals, 14) of the nasal verte the proximal or *pleurapophysial* element of such arch; and the same re tition of the characteristic connections of the bone, 20, which enabled Cu and Geoffroy to recognise its special homology with the palatine bone in fish, establishes its claim to be equally regarded in the crocodile as the ple apophysis of its vertebral segment; although it now affords but a partial tachment to the bone 21, which forms the next element of the inverted a This bone, the *hæmapophysis*, has undergone a striking change in its pro tions by development both in length and breadth: it is connected not only v no. 20 behind and with no. 22 before, but with the elongated spine, no. 15, o own vertebra, and with the lacrymals, 73, above; with its fellow of the oppo side below, and with a well-developed proximal element, no. 26, of a str diverging appendage behind. The *hæmal spine*, no. 22, is divided, and arch is completed by the symphysial junction of the two halves at H IV. T nasal aperture or entry to the air-passages forms the span or area of much-modified inverted arch constituting the upper jaw of the crocod The two proximal elements of the arch, nos. 20 and 21, continue to s outwards and backwards exogenous diverging processes; but they con tute a smaller proportion of the bones than in fishes, and both processes rectly support distinct bones representing the *diverging appendage* of arch, and serving to fix and attach it to the succeeding arch. The pleura physial appendage (pterygoid, 24) soon coalesces, however, with its fell and with the centrum of its own vertebra (vomer, 13), and then expands unite by a broad sutural surface with the coalesced centrums of the fron and parietal vertebræ (9 and 5). A second osseous piece (ectopteryg 24′) diverges from the pleurapophysis external to the preceding and attac it to the hæmapophysis, to the hæmapophysial appendage, and to the p apophysis of the frontal vertebra. The strong diverging ray from the hæ apophysis is teleologically subdivided into nos. 26 (malar) and 27 (squamos and firmly attaches the maxillary arch to the pleurapophysis (28) of the m dibular one.

In the chelonian reptiles the modifications of the nasal segment of t skull adhere pretty closely to the type of those in the crocodile; the centr is more independent and better developed, but the divisions of the neu spine have coalesced with their neurapophyses: the diverging appendag 26 and 27, are usually developed into broad and flat bones. In many liza we find the nasal centrum divided but the neural spine single: the hæn spine is, also, single, as a general rule, and sends upwards and backward process to join the neural spine, divide the area of the hæmal canal, a terminate the vertebral series anteriorly. The hæmapophysial diverging a pendage commonly resumes its long and slender ray-like proportions, and joi the parapophyses of both frontal and parietal vertebræ as well as the pro imal end of the pleurapophysis of the mandibular arch. In serpents bo divisions of this appendage are absent (indicating the inferior character the bones 26 and 27 in general homology), but the two parts of the pleura physial appendage, 24 and 24′, are retained and serve as levers in the mov ments of the maxillary arch. The spine of that hæmal arch is single, a commonly united only by lax and elastic ligaments with the hæmapophys

Fig. 22.

... of the skull of the crocodile (*Alligator lucius*).

ch may be divaricated like the halves of the mandibular arch, so as to en the mouth laterally; and this free suspension and incomplete closure he principal costal arches of the cranium in serpents repeats in an inter-ng manner the characteristic free and open condition of all the costal arches heir trunk. In the genus *Typhlops* the diverging appendage of the to-maxillary arch is reduced to the primitive condition of a long and der ray. In anourous batrachians a long and slender backwardly pro-ed exogenous process of the hæmapophysis (maxillary) joins a shorter ancing exogenous process of the distal division of the next pleurapo-sis (tympanic): but in the tailed species the maxillary arch is fixed only . broad (pterygoid) appendage; and both maxillary and premaxillary retain · their essential connections as forming the inferior arch of their segment. he proteus and siren the pleurapophysis (maxillary) is almost obsolete.

The bones nos. 24, 24′, 26 and 27, being shown to be the least constant nbers of the group forming the nasal segment, and to form by their posi- and direction, the diverging appendages of the hæmal arch H IV, there ains in the skull of the crocodile only the bone 73, which by its position front of the orbit and its relation to the lacrymal duct, is to be referred the great anterior suborbital mucous bone in fishes to the dermal skele- In like manner the palpebral or supra-orbital scale-bones are to be ex-ded from the category of the pieces of the endoskeleton. The small and onstant ossifications in the capsule of the organ of smell, together with the rcely ossified sclerotals (17), the small petrosal, 16, and the columelliform es, 16′, are intercalated portions of sense-capsules and appendages re-ble to the system of the splanchnoskeleton.

Thus the endoskeletal system of bones of the head of the crocodile are natu-y arranged in four segments, each composed of a centrum with a neural a hæmal arch. The hæmal arches have been subjected, as in the trunk, nost modification; that of the occipital vertebra having been displaced; t of the parietal vertebra detached from its segment and arrested in its elopment; whilst that of the frontal vertebra is articulated in a very small portion to the parapophysis of its own segment, but chiefly to that of the ietal segment, with paroccipital connections also; it is immensely de-oped, the hæmapophysial portion being the chief seat of extension. The mal arch of the nasal segment is also very large, but shows as much ess of development in breadth as that of the frontal vertebra in length. e diverging appendage is more complex than in fishes: one piece indeed, 25, fig. 5, is absent, but three others, 24′, 26 and 27, have been superadded. e diverging appendages of the frontal and parietal vertebræ cease to be eloped in every class above that of fishes; but that of the occipital hæmal h, though it no longer shows the luxuriant profusion of rays that distin-shes it in fishes, begins to assume a more fixed and definite character with re special powers and independent movements of its constituent parts. e first segment (53), doubtfully and obscurely recognizable in any fish, is nceforth a constant and important bone, and is always single: the next ment consists as exclusively of two bones, connate, indeed, in batra-ans: the distal segment presents two jointed rays (digits) in the *Amphi-a didactylum*; three rays in *Amph. tridactylum* and the proteus and four s in the *Siren lacertina*; it branched into as many as nine rays in the ex-ct ichthyosaurs; but they never exceed five in the existing saurians, which mber is presented by this appendage in the crocodile (57, fig. 22.)

Birds.—The cranium of the bird offers the extremest instance of a homo-ically compound bone, and its development the clearest evidence of that nciple of unity of composition which lies at the bottom of all the modifications of the cephalic division of the vertebrate endoskeleton. Although, a general rule, the separate cranial bones can be discerned only at a very ea period, yet in those birds in which the power of flight is abrogated the in cations of the primitive centres of ossification endure longer, and in species here selected for the illustration of the cranial segments (fig. 23) constituent bones of the skull, though figured of their natural size, have, w the exception of the basioccipital, 1, and basisphenoid, 3, and the two bon 6 and 8, which coalesce with the petrosal, 16, been separated by macerat merely. I may remark, however, that in all birds, certain bones, wh coalesce with others in the cranium of most mammals, always retain th primitive individuality; the tympanic (28) and the pterygoid (24) for ample.

The hindmost segment of the cranium (N 1, fig. 23) so closely repeats characters of the epencephalic neural arch of the crocodile (fig. 18), as render a separate and full view of it unnecessary for the illustration of vertebral character. The basioccipital (1) still developes the major part the single articular condyle, and sends down a process, more marked in struthious genera, and especially the dinornis, than in most other birds: all respects this primitively distinct bone retains the character of the *centr* of its vertebra.

The exoccipitals, 12, contributing somewhat more to the occipital cond than in the crocodile, develope, as in that reptile, the paroccipital (24) as outstanding exogenous ridge or process: but it is lower in position than the crocodile: the proper *neurapophysial* characters of no. 2 are fully ma tained. The supraoccipital (3) now begins to manifest more strongly t flattening and development in breadth, by which the spinous elements lo the formal character from which their name originated, and are convert from long into flat bones. We saw the first step in this most common of t changes to which one and the same endoskeletal element is subject, in t detached neural spine of the atlas of the crocodile: that of the occipi vertebra of the same animal presented another stage in the metamorphos we have a third degree in the bird, and the extreme of expansion is attain in the human subject (fig. 25, 3), where the spine is sometimes develop like that of the parietal vertebra, from two centres. But the arrested st in this strange change of form and proportion demonstrate the essent nature of the part, as the neural arch, whilst the constancy of the charact of connexion is shown by this crown of the arch of the occipital verteb having the exoccipitals as its piers or haunches from the fish to the hum subject. It always protects the cerebellum; is absent in the frog where th organ is a mere rudiment; and is present in the crocodile in the ratio the superior size of the cerebellum. The further development of the cer bellum is the condition of the superior breadth of the spine or crown the epencephalic arch in the bird.

The arguments that determined the nature and displacement of the hæm arch of the occipital vertebra in the crocodile apply with equal force to th in the bird. The extent of the displacement, it is true, has been greate not seven, but seven-and-twenty vertebræ may intervene between the pla of the scapulo-coracoid arch and the remainder of its proper segment co stituting the occipital region of the simple cranial box in the bird. But th difference of extent ought no more to mask the real relationship of su costal arch to its centrum, than the degree of development of the spine the occipital vertebra affects the general homology of that element.

In the ostrich, and other struthious birds, the hæmal arch of the occipit vertebra has retained much of its embryonic proportions. The *pleurap*

Fig. 23.

ial part (51) has, also, retained its slender rib-like form* ; it has coalesced ı the *hæmapophysis* (52), and the inverted arch is completed, as in the ·odile, by a hæmal spine, as much modified in form by flattening and ex-sion as is the neural spine represented by the supraoccipital (3). The rging appendage of the occipito-hæmal arch also retains much of its nitive simple character: a long and slender bone (53) supports two rays 55), and there is an attempt at three at 57, of which one is short, atrophied anchylosed to the rest. In the two small bones (56, 56) interposed be-en this and the preceding segment, we recognise the special homologues he carpal series in the crocodile and fish: in 54 we have the ulna, in 55 radius, in 53 the humerus, in 57 the metacarpus; in *d* 3 and *d* 4 the rudi-its of the digits so numbered in the crocodile (fig. 22) and the mammal . 24). The evidences of the unity of plan in the construction of the ular limb, whether it be an arm with the prehensile hand, a hoofed fore- a wing, or a fin, are admitted by all; the same scapula, humerus, anti-chial, carpal, metacarpal and phalangial bones are readily recognised by the ı in comparative osteology in the ape, the horse, the whale, the bird, the oise and the crocodile. The beautiful simplicity of the fundamental basis ıll these adaptations of structure is descanted upon in all our popular ological treatises. But the higher law governing the existence of these cial homologies has attracted little attention in this country. Yet the uiry into that more general principle of conformity to type according to ch it has pleased the Creator of organic forms to restrict the manifesta-ıs of the variety of proportion and shape and substance and even relative ition of the limbs requisite for the various tasks assigned to the vertebrate cies, is one that by no means transcends the scope of the comparative tomist. And the conclusion to which my comparisons have conducted is, that one and the same element, viz. the diverging appendage of the ipital vertebra, forms in every case—to whatever adaptive modifications ay be subjected—the part recognized by the general term, 'anterior' or perior extremity.'

The second segment of the skull has for its *central* element a bone (fig. 5), which in the bird, as in other ovipara, is connate with that (9) which ıds in the same relation to the third cranial segment; the proof of the ural distinction of these segments is given by the neural, N II, N III, l hæmal, H II, H III, arches. Probably the circumstance of the bodies those vertebræ being formed by ossifications of the fibrous capsule of the ochord, representing the external or cortical parts only of such centrums, y be the condition, or a favourable physical cause of such connation. e neural arch of the parietal vertebra retains the same characters which irst manifested in fishes. Besides the *neurapophyses* (6) impressed by the sencephalic ganglia and transmitting the trigeminal nerves, besides the itly expanded and again, as in fishes, divided neural spine (7), the *parapo-ysis* (8) is independently developed. It is of large proportional size; and, ing to the raised dome of the neural arch, is relatively lower in position ın in the crocodile; it sends downwards and outwards an unusually long astoid' process, and forms a large proportion of the outer wall of the amber of the internal ear with the bony capsule of which it speedily coalesces. The hæmal arch of the parietal vertebra (H II) is more reduced than in crocodile, and owes much of its apparently typical character to the re-ition of the thyrohyals (16, 17) borrowed from the branchial arches of the

* The very common modification of form which this element undergoes in becoming ex-ided into the broad scapula of man and other mammalia, appears to have influenced Oken his idea of that bone being the homologue of a congeries of ribs.

visceral system, which are feebly and transitorily manifested in the embr bird. These spurious cornua project freely or are freely suspended, and a the subjects of singular and excessive development, as has been exemplifi in the chapter on Special Homology.

The bones (10) of the third neural arch protect a smaller proportion of t prosencephalon than in the crocodile, but maintain their *neurapophysial* rel tion to it and to the optic nerves: the *neural spines* (11) cover a larger proporti of the hemispheres, and, with their homotypes (7), exhibit a marked increa of development in conformity with that of the cerebral centres protected their respective arches. The *parapophysis* of the frontal vertebra (12) relatively smaller in the bird than in the cold-blooded vertebrates, and rarely ossified from an independent centre; but I have seen this in the eme and it appears to have been constantly an autogenous element in the dinorn The hæmal arch of the frontal vertebra has been transferred backwards the parietal one; its *pleurapophysis* (28), which is simple, as in the crocodi articulating exclusively with the parietal parapophysis (8), though this some birds unites with that of the frontal vertebra. In the young ostri and many other birds traces of the composite character of the *hæmapophys* are long extant; and bear obviously a homological relation to the teleolog eally compound character of the element in the crocodile: for the piec nos. 29, 29′, 30′ and 31 ultimately, and in most birds early, coales with each other and with the *hæmal spine* (32), the halves of which are co fluent at the symphysis.

The *centrum* (13) of the nasal vertebra is always single, and, when it do not remain distinct, coalesces with the neurapophyses, 14, and pleurapophyse 20, of its own segment, and sometimes, also, with the rostral production of t frontal centrum (9): it is elongated and pointed at its free termination, a deeply grooved above where it receives the above-named rostrum; indicati by both its form and position that it owes its existence, as bone, to the oss fication of the outer capsule of the anterior end of the notochord. In t ostrich the long presphenoidal rostrum intervenes between the vomer (and prefrontals (14). These latter bones manifest, however, as has bee shown in the paragraph on their special homology (p. 214), all the essenti *neurapophysial* relations to the rhinencephalon and olfactory nerves: b they early coalesce together, or are connate, as in the tailless batrachian The *neural spine* (15) is divided along the middle line; but in most birds t suture becomes obliterated and the spine coalesces with its neurapophyse with the frontal spine and with those parts of the hæmal arch of the nas vertebra with which it comes in contact.

The *pleurapophyses* (fig. 23, 20) of this inverted arch retain their typic connections with the nasal centrum and neurapophyses at one end, and wi the hæmapophysis (21) at the other end, and they also support the consta element of the diverging appendage of the arch, no. 24. The *hæmap physis* (21) resumes in birds more of its normal proportions and elongate slender form: but the *hæmal spine* (22) is largely developed though und vided, and sends upwards and backwards from the part corresponding to t symphysis of the spine, when this element is divided, a long pointed proce (22′), which joins and usually coalesces with the neural spine (15) and divid the anterior outlet of the hæmal canal into two apertures called the nostril The modification of the inferior arch of the nasal vertebra in the lizard trib is here repeated. The pleurapophysial *appendage*, 24, connects the palat maxillary arch with 28, and in the ostrich and a few other birds, also with 5 the second or hæmapophysial ray of the diverging appendage is dev loped in all birds, as in the squamate saurians; combining the movemen

Fig. 24.

Disarticulated bones of the neural (N I to IV) and hæmal (H I to IV) arches, and appendages, of the skull of a hog (*Sus Scrofa*) e hæmal arch of the nasal vertebra with that of the frontal vertebra, consisting of the two styliform ossicles (26 and 27) which extend from the apophysis, 21, 21″, to the pleurapophysis, 28: the essential relationship of ompound ray, 26 and 27, with the nasal vertebra, is indicated by their ..ning confluent with its hæmapophysis (at 22″), whilst they always main-.an arthrodial articulation with the pleurapophysis (28) of the succeeding .bra.

.e bones of the splanchno-skeleton intercalated with the segments of the -skeleton in the bird's skull are the petrosal (16), between the neural .s of the occipital and parietal vertebræ, early coalescing with the ele-.s of those vertebræ with which it comes in contact: the sclerotals (17), posed between the frontal and nasal neural arches: and the thyro-hyals), retained in connection with the debris of the hæmal arch of the parietal .bra, H II. The olfactory capsule remains cartilaginous. The dermal (73) is well-developed and constant: a second supraorbital dermal bone .casionally present. All the endoskeletal bones manifest, under every .ive modification, the segmental arrangement, and it is difficult to con-'late the disposition of the cranial bones in fig. 23, as in figs. 22 and 5, .d the primary segments of the encephalon in the series of arches closed .ctively by the bones N I, N II, N III, N IV, together with that of the .sponding number of arches closed below, at H IV, H III, H II and H I, .ut a conviction that the type illustrated in fig. 15 is that upon which segments of the skull have been constructed. This conclusion might . forced, in respect to the occipital vertebra, were its displaced hæmal arch .ppendages to be viewed without reference to their relative position and .ections in the lower vertebrate classes; but it will be confirmed and .n to be agreeable to nature and to the recognised kinds and grades of .fication to which the elements of one and the same vertebra are subject, .serving in the young bird the distinct pleurapophysial elements of those .cal vertebræ, beyond which the corresponding elements of the occiput . retrograded, in obedience to the functions which the hæmal arch of vertebra and its appendages are destined to perform in the feathered

.ummals.—If the foregoing views of the general homology of the bones e skull be agreeable to their essential nature, we should expect that the and additional modifications, in the mammalian class, which tend to .re those relations would be seated in the appendages and peripheral .nts of the endoskeletal segments, or in the capsules and appendages of .ecial organs of sense.

.ave selected with the view to test such anticipation the skull of a young .derm*, and, after successively disarticulating the segments in the order .ich they have been previously described, I have given a side view of (fig. 24) arranged in correspondence with the figures 23, 22, and 5.

e neural arch of the occipital vertebra, N I, agrees with that of the bird and dile in the coalescence of the *parapophysis*, 4, with the *neurapophysis*, .t the process, 4, now descends from the lower part of the arch, and, many other mammals, is of great length. An articular condyle is also .oped from each neurapophysis which articulates with the concave an-zygapophysis of the atlas, and is the homotype of the posterior zyga-.sis in the trunk-vertebræ. The centrum (1) is reduced, like that of .las, to a compressed plate, and its hinder articular surface is not more

* .e skull of the ruminant is perhaps still better adapted to demonstrate the vertebral .ns of the cranial bones: that of the sheep is the subject of the diagram for this pur- the concluding volume of my 'Hunterian Lectures.'

developed than is the front one of the centrum of the atlas, with which, deed, it is loosely connected by ligament. The expanse of the occipi spine, 3, has been governed, agreeably with a foregoing remark, by the perior development of the cerebellum.

The hæmal arch of the occipital vertebra is represented, like those of cervical vertebræ, by the *pleurapophysial* elements only (51); but these most mammals, are developed into broad triangular plates with outstand processes: that called 'spine' and 'acromion' is exogenous; but that cal 'coracoid' is always developed from an independent osseous centre (a ru mental representative of the *hæmapophysis*, 52), which coalesces with pleurapophysis in mammalia, and only attains its normal proportions, co pleting the arch with the hæmal spine (episternum) in the monotremes.

In many mammals the arch is completed by bones (fig. 25, 52′), apparen the hæmapophyses of the atlas, which have followed the occipital hæmal a in its backward displacement, but not quite to the same extent.

The diverging appendage, though retaining the general features of primitive radiated form, has been the seat of great development and m modification and adjustment of its different subdivisions (53–57) in relat to the locomotive office it is now called upon to perform.

With the exception of this excess of development of the appendage, defective development and displacement of the hæmal arch, and the coa cence of the parapophyses in the neural arch, there are few points of res blance which are not sufficiently salient between the segment N I, H I in mammal, and that so marked in the fish (fig. 5). And, if the interpreta of the more normal condition of this segment in the lower vertebrate, cording to the archetypal vertebra, fig. 15, be accepted, then the expla tion here offered of the nature of the modifications of the special homolog of the constituents of the occipital segment by which that archetyp masked in the mammal, may be confidently left to be confirmed by judgement of the unbiassed student of homological anatomy.

In commencing his comparisons of the second segment of the skull with typical vertebra, he will be unexpectedly gratified by finding, in the imma mammal, the *centrum*, 5, naturally distinct, and the hæmal arch, H II, retain its connections with the rest of the segment, and by means of a more c plete development of the pleurapophyses (38) than in any of the inferior breathing vertebrates. He may now separate, without artificial divisio any compound bone, the entire parietal segment, but he brings away wi the petrified capsule of the acoustic organ, and the anchylosed distal piece of the maxillary appendage, which more or less encumbers and conceals typical character of the neural arch of the parietal vertebra in every mamr least so, however, in the monotremes and ruminants. The *neurapophyses* of the parietal vertebra, like the mesencephalic segment of the brain, are little more developed in mammals than in the cold-blooded classes: they notched in the hog and perforated in the sheep by the larger division the trigeminal, and they send down an exogenous process, which articul and sometimes coalesces with the appendage (24) of the palato-maxil arch. The *neural spine* (7), always developed from two centres, often ve expanded, and sometimes complicated with a third intercalary or in parietal osseous piece, is occasionally uplifted and removed from its n apophyses by the interposed squamous expansion of the bone 27; but which reminds one of the occasional separation of the neural arch from centrum of the atlas in fishes, is a rare modification in the mammalian c A still rarer one is the separation of the halves of the parieto-neural s from each other by the extension and mutual junction at the median

:he occipital and frontal spines. A specimen of this, in a species of *us*, which repeats the common modification of the parts in fishes, is pre-ed in the museum of the Royal College of Surgeons. The *parapophysis* always commences as an autogenous element by a distinct centre of ossi-:ion, as shown in the human fœtus, fig. 11, 8; it speedily coalesces with petrosal, but otherwise retains its individuality in some of the lower mam-s, as *e.g.* in the echidna (fig. 12, 8): or it coalesces with the curtailed tal pleurapophysis 28, or with the maxillary appendage 27, or with both e and the pleurapophysis of its own vertebra (38), when the complex nporal bone' of anthropotomy is the result. In most mammals the *pleur-ophysis* (38) retains its primitive independency and rib-like form, with ılly the 'head' and 'tubercle'; but by reason of its arrested growth it been called 'styloid' bone or process. Sometimes it is separated from short *hæmapophysis*, 40, by a long ligamentous tract, sometimes it is imme-ely articulated with it, or by an intervening piece. The *hæmal spine*, 41, ually small, but thick and always single. The rudiments of hypobranchial nents (46) are retained as diverging appendages of the parieto-hæmal arch ll mammals, and have received the special names of 'posterior cornua,' thyrohyals,' from their subservient relationship to the larynx.

ı the frontal segment the *centrum*, 9, and *neurapophyses*, 10, very early esce. Two separate osseous centres mark out the body (fig. 26, C, 9), each neurapophysis has two distinct centres (*ib.* 10, 10), the optic foramina) being first surrounded by the course of the ossification from these ıts. The superior development of the neurapophysial plates (fig. 24, 10), ompared with those of the parietal vertebra (6), in most mammals, har-izes with the greater development of the prosencephalon; but the chief : of this segment of the brain is protected by the expanded spines of the :tal (11) and parietal (7) vertebræ, and by the intercalated squamosals (27). many ruminants the bifid element 11 developes two spinous processes ed side by side as in the anterior trunk-vertebræ of the *Tetrodon*; but project beyond the integument and are called 'horns.' The appendicular e (27) not only usurps some of the functions of the proper cranial neurapo-ses, but, likewise, the normal office of the frontal pleurapophysis (28), in support, viz. of the distal elements of the hæmal arch (29, 32), which now culate directly with 27, in place of 28 as in all oviparous vertebrates. The *pleurapophysis* of the frontal vertebra (28) is almost restricted in the nmalian class to functions in subserviency to the organ of hearing, is etimes swollen into a large bulla ossea, like the parapophyses and pleurapo-ses of the cervical vertebræ of *Cobitis*, Pl. I, fig. 7, *pl*, *x*; it is sometimes luced into a long auditory tube, and sometimes reduced to the ring support-the tympanic membrane. Yet, under all these changes, since its special ology is demonstrable with 28 in the bird (fig. 23) and crocodile (fig. 22) as as with the teleologically compound bone, 28 *a*, *b*, *c*, *d*, in the fish (fig. 5), ikewise must its general homology, which is so plainly manifested in fish, be equally recognised. The frontal *hæmapophysis* (fig. 24, 29, 30), the corresponding half of the *hæmal spine* (*ib.* 32) are connate on each in all mammals, and become confluent at H III, in most. The hæmal of the frontal segment of the skull, as in other air-breathing vertebrates, no diverging appendage, unless the tympanic otosteals be so regarded, dea which is not borne out by their development.

he nasal segment (N IV, H IV) is chiefly complicated by the confluence of s of the enormously developed olfactory capsules (18) in the mammalian s, and its typical character is masked by the compression and mutual coa-ence of the *neurapophyses*, 11. The *centrum* is usually much elongated, t 13, and soon coalesces with both *neurapophyses* (14) and nasal capsules in the hog. The *neural spine* (15) is usually divided, but is sometimes singl *e. g.* in *Simia.* In the rhinoceros it supports a dermal spine or horn. T *pleurapophysis* (20) or proximal element of the hæmal arch of the nasal ve tebra has its real character and import almost concealed by the excessi development of the second element of the arch (21), which resumes in mar mals all those extensive collateral connections which it presented in the cr codile; and to which are sometimes added attachments to the expanded spi of the frontal vertebra, as well as to that of its own segment. The pleurap physis however, besides its normal attachment to its centrum, 13, sends ur process to the orbit, in order to effect a junction with its neurapophysis whi sometimes appears there, as the 'os planum' of anthropotomy. The *hæm spine* (22) is developed in two moieties, which never coalesce together, though, in the higher apes, and at a very early period in man, each h coalesces with the hæmapophysis, and repeats the simple character of t corresponding elements (rami) of the succeeding (mandibular) arch.

The *appendicular* element (24) which diverges from the pleurapophy (20), contributes to fix and strengthen the palato-maxillary arch by attachi it to the descending process of the parietal centrum (5); with which, in m mammals, it ultimately coalesces. The other elements of the diverging me ber of the arch correspond in number and in the point of their divergen with those in birds, chelonians and crocodiles. They are two in number, su ceeding each other, and both become the seat of that expansive developme which is followed by the multiplication of their points of connection; tl the proximal piece ('malar' 26) articulates in the hog not only with t hæmapophysis (21) from which it diverges, but likewise with the muco-derr bone, 73. The distal piece of the appendage (squamosal, 27) expands as diverges, and fixes the naso-hæmal arch not only to the frontal pleura physis (28), but also to the frontal, parietal and occipital neurapophyses a spines: it also affords, in the hog, as in other mammals, an articular surf to the frontal hæmapophysis (29).

The development of an osseous centre in the cartilage of the snout the hog, and the homologous 'prenasal' ossicle in certain fishes, the ca *e. g.*, might be regarded as rudiments of terminal abortive segments m anterior than the nasal vertebra. The multiplied points of ossification in vomer have been, also, deemed indications of that bone being, like the vom ine coccygeal bone in birds, a coalescence of several vertebral bodies. course, *à priori*, the segments in the cranial region of the endoskele might as reasonably be expected to vary in number in different species, the segments in the thoracic or sacral regions. I have not, however, be able to determine clear and satisfactory representatives of more than f vertebræ in the skull of any animal; and the special ossifications in the na cartilages appear to me to belong to the same category of osseous parts, the palpebral bones in certain crocodiles and the otosteals.

Man.—Arriving, finally, in the ascensive survey and comparison of archetypal relations of the bones of the vertebrate skull, at Man, the highest a most modified of all organic forms, in which the dominion of the controll and specially adapting force over the lower tendency to type and vegetat repetition is manifested in the strongest characters, we, nevertheless, find vertebrate pattern so obviously retained, and the mammalian modification o as illustrated in the preceding paragraph and diagram, so closely adhered as to call for a brief notice only of those developments of the comm elements which impress upon the human skull its characteristic form a proportions.

The neural arch of the occipital vertebra differs from that of the hog a much greater development of the *neural spine* (fig. 25, 3) and a much

Fig. 25.

elopment of the parapophysis. This, as in other mammals, is not only an genous process of the *neurapophysis*, 2, but is commonly reduced to a e " scabrous ridge extended from the middle of the condyle towards the of the mastoid process" (Monro, *l. c.* p. 72)—the " eminentia aspera iculum rectum lateralem excipiens " of Soemmerring: the knowledge of general homology, however, makes quite intelligible and gives its true rest to the occasional development of this ridge into a 'paramastoid' paroccipital process, which now, however, projects, like the true ' mastoid,' nwards from the basal aspect of the cranium (*ante*, p. 30).

he occipital *pleurapophysis*, *pl*, 51, shows the same displacement as in r mammals, but is still more expanded in the direction of the trunk's , and its exogenous (acromial) process is still more developed. The *hæm-ohysis* (52), originally distinct, has its development checked and speedily esces with the pleurapophysis.

the bone 52′ be the special homologue of the bone, 58, Pl. I. fig. 2, in the —and considering the backward displacement of 51 and 52, its anterior tion to them in man is no valid argument against the determination,— we may adopt the same general homology, and regard the clavicle, in relations to the vertebrate archetype, as the displaced hæmapophysial ent of the atlas, to which segment its true relative position is shown in same low organized class in which the typical position of the scapular is likewise retained.

he adaptive developments of the radiated appendage of the occipital al arch reach their maximum in man, and the distal segment of the ap-dage constitutes in him an organ which the greatest of ancient philoso-rs has defined as the " fit instrument of the rational soul ;" and which lustrious modern physiologist has described " as belonging exclusively to —as the part to which the whole frame must conform"*. And these ex-sions give no exaggerated idea of the exquisite mechanism and adjust-t of its parts.

is no mere transcendental dream, but true knowledge and legitimate of inductive research, that clear insight into the essential nature of the n, which is acquired by tracing it step by step from the unbranched oral ray of the protopterus to the equally small and slender but bifid oral ray of the amphiume, thence to the similar but trifid ray of the eus, and through the progressively superadded structures and perfec-s in higher reptiles and in mammals. If the special homology of each of the diverging appendage and its supporting arch are recognisable Man to the fish, shall we close the mind's eye to the evidences of that er law of archetypal conformity on which the very power of tracing the r and more special correspondences depend ?

ntil the alleged facts (p. 117) are disproved, demonstrating change of tion to be one of the modifications by which parts of a natural and re-nisable endoskeletal segment are adapted to special offices, and until conclusions (p. 118) deduced from those facts are shown to be fallacious, I t retain the conviction that, in their relation to the vertebrate archetype, human hands and arms are parts of the head—diverging appendages of costal or hæmal arch of the occipital segment of the skull†.

Bell (Sir Charles), " The Hand." Bridgewater Treatise, 1833, pp. 16, 18.
όνον δὲ καὶ ἀμφιδέξιον γίγνεται τῶν ἄλλων ζώων ἄνθρωπος.—*Aristotle.*
As another example of the new light and interest which a knowledge of general homo-gives to the facts of abnormal anatomy in the human species, I may cite the remark-case described by Sir C. Bell (*op. cit* p. 52), of the boy ' born without arms,'—' but who lavicles and scapulæ.' Here development was arrested at the point at which it is normal

The *centrum*, 5 *c*, of the parietal vertebra gives, in the human fœtus, th same evidence of its essential individuality, by the same absence of the mas of connation which somewhat concealed it in the oviparous classes, a we have already noticed in the lower mammal (fig. 24). The *neurapo physes* (6) rise higher to reach their proper *spine* (7) in the lofty cranial dom of man, of which that divided and enormously expanded element forms th greatest part of the roof: but the base of the neurapophysis continues to b perforated by the homologous divisions of the nerve (*tr*) that notches it i the cod-fish (fig. 5, 6 *tr*). The *parapophysis* (8) retains its autogenous c independent character in relation to its proper neural arch, the 'additamenta suture by which it manifests its normal relations to the neural spine (7) bein persistent; but it speedily coalesces with the acoustic capsule, 16 (fro which it is artificially separated in fig. 25), and with the modified *pleurap physis*, 28, as has been already explained in the chapter on 'Special Homo logy' (Mastoid, pp. 29–42).

The proper *pleurapophysis* (38) of the parietal vertebra ordinarily become confluent with contiguous and coalesced portions of the parapophysis, 8, an acoustic capsule, 16; and the ossified portion of the *hæmapophysis*, 40 *h*, separated from it by a long ligamentous tract, and becomes confluent wi the *hæmal spine*, 41 *hs*. The entire inverted arch exhibits the usual arreste growth characteristic of the air-breathing vertebrates, and its appendag are represented by the still retained 'hypobranchial' elements, 46, of th splanchnic arches, which are so voluminously developed in the fish.

The *centrum* and *neurapophyses* (9, 10) of the frontal vertebra manifest th same speedy coalescence as in other mammals. The *spine*, 11, though develop from two lateral moieties, regains its normal unity, as a general rule, in m by the obliteration of the median suture: its transverse and vertical expan here attain their maximum. The *parapophysis* (12) is developed, as in th occipital segment, as an exogenous process, called 'external angular or o bital' in anthropotomy, but from the neural spine instead of the neurap physis. This element is perforated by its characteristic nerve (*op*). The *pleu apophysis*, 28, is now separated from its parapophysis, 12, by both parts, 27 a 26, of the diverging appendage of the maxillary arch; but yet it is interesti to note that it is still connected through the medium of these with the sa element to which, agreeably with the greater retention of the vertebra archetype, it directly articulates in the fish (fig. 5, 12, 28 *a–d*). The inte calated piece (27) further interposes itself, as in other mammals, betwe the pleurapophysis, 28, and hæmapophysis, 20, of the frontal segment, direct articulating with the latter and leaving the proximal element of the arch (2 reduced in man to its subordinate function of sustaining the ear-drum. T *hæmapophysis*, 20, and *hæmal spine*, 32, are connate, and soon coalesce with th

in the *Anguis*, *Pseudopus*, and some other limbless and snake-like lizards. The usual p dominating development of the scapular appendage has bred so prevalent an idea of the su ordinate character of the supporting arch, that the existence of the arch minus the appe age, is adverted to not without a note of surprise in the above-cited and other excellent wor General homology, however, teaches that a vertebral arch is a more constant and import part than its appendages; and, that, being anterior in the order of development, it may expected, in cases where development is arrested, whether normally in accordance with t nature of the species or abnormally as an individual defect, to be present when the diverg appendages are absent. Sir Charles Bell, well recognising the primary function of the mo fied occipital rib in relation to breathing, observes, in reference to the above-cited case, " would do well to remember this double office of the scapula and its muscles, that, whilst i the very foundation of the bones of the upper extremity, and never wanting in any anim that has the most remote resemblance to an arm, it is the centre and point d'appui of t muscles of respiration, and acts in that capacity where there are no extremities at all p. 52.

›osites at the symphysis menti; and the whole distal portion of the inverted h of the frontal segment is then formed by a continuous bar of bone, modi-l in its form and articulation, and by its dental appendages, in subserviency mastication and other functions in relation to the human mouth.

Ve recognise the *centrum* of the nasal vertebra in the human skull by the ition and connections of the bone, 13, notwithstanding it has undergone extreme a divergence from the ordinary cylindrical shape of such elements, ts homotype at the opposite extreme of the vertebral column in birds, ch Cuvier compares to a 'soc-de-charrue': it is, in fact, more compressed vertically developed than in the hog (fig. 24, 13); but it is shorter, and nmonly retains its original individuality. It directly supports the similarly lified compressed and, also, coalesced *neurapophyses*, 14, which, termi-ing in like manner the series of their vertebral homotypes anteriorly, have lergone the extremest modification. But the arguments proving the lesced prefrontals of the frog, the bird and the mammal to be the special nologues of the bones so called in the fish, establish, as a corollary, their eral homology with those bones, which retain in so much greater a degree, unmistakeably, their neurapophysial characters in that lowest class of l-blooded vertebrates. The nature of the additional complication by ch those vertebral or archetypal characters are further masked in mam-s, has been already explained in relation to the nasal neurapophyses of hog. The olfactory nerves are transmitted in man, as in that and most er inferior mammals, by numerous foramina, 14, *ol*. The *nasal spine*, 15, is ded, but much-restricted in its growth, and presents a singular contrast hat respect to its homotypes, 11, 7, 3, in the succeeding cranial vertebræ. development of the neural arch of the nasal vertebra is so modified in n, so contracted as well as retracted, that the orbits, instead of being hed apart and directed laterally, have approximated by a kind of reci-cal rotation towards the median plane, and have thus gained a directly erior aspect.

ieneral homology perhaps best explains the import of the continuation he small and seemingly insignificant bones (20, *pl*) from the roof of the uth "up the back part of the nostrils to the orbit," where they are nected "to the *ossa plana* and *cellulæ ethmoideæ* by the ethmoid suture." it the connection is the best possible for the functions of the bone we feel assured, without the sentiment being damped by discerning in it, ie same time, the attempt to retain the type, and repeat those constant con-tions of the *pleurapophysis* in question, not only with its centrum (vomer), also with the modified neurapophyses of its proper segment (prefron-with coalesced olfactory capsules constituting the compound 'ethmoid e' of anthropotomy). The connections of the pleurapophysis, 20, with its napophysis, 21, in front, and its diverging appendage, 24, behind, are also ined in man; and in short, all those characters that, depending on the ntial nature of the palatine bone as the pleurapophysis of its vertebral ment, have served to indicate its special homology from man to the fish, iout doubt or difficulty, to all anatomists (see Table I.).

The *hæmapophysis* (21) has the usual mammalian expansion, but is unu-lly short in man, and coalesces unusually early with the corresponding ety of the *hæmal spine* (22). Besides the normal and constant connec-is with 20 and 22, the hæmapophysis, 21, articulates with its fellow, with centrum (13), neurapophysis (14, os planum), and spine (15), of its n vertebra, with the spine of the frontal vertebra (11), with the detached tion of the olfactory capsule (19), and with the muco-dermal bone (73). also affords a large surface of attachment to the proximal piece of its diverging appendage (26), which, in addition to the more constant con nections with 21 and 27, articulates in man with the neurapophysis (10 and parapophysis (12) of the frontal vertebra. The distal extremity of th second bone (27) of the diverging appendage attains its maximum of expan sion in man, and besides its connection with 26, and the glenoid articulatio for the hæmapophysis, 29, it joins the parietal neurapophysis, 6, and spine, 7 and sometimes also (in the melanian race) the spine (11) of the frontal ver tebra: and it speedily coalesces with the reduced pleurapophysis, 28, of th frontal vertebra, and with the parapophysis (8) of the parietal vertebra, to gether with a portion of the capsule of the acoustic organ.

In reviewing the general characters of the human skull in reference to th vertebrate archetype, we find the occipital segment simplified by the atroph and connation of its parapophyses and hæmapophyses; and modified chiefl by the excessive growth of its neural spine and pleurapophyses, and by th backward displacement of the latter element, as in all other air-breathin vertebrates. The parietal segment, retaining, like the occipital one, the mor normal proportions of its centrum and neurapophyses, is still more remark able for the vast expanse of its permanently bifid spine. As in most cold blooded vertebrates, the parapophysis preserves its independence in respect t the neural arch of its own segment. The hæmal arch retains its almost fœta proportions, but is less displaced than in some of the inferior air-breathin vertebrates. The primitive individuality of the centrum of the parietal vertebr is a feature by which the human subject, together with all other mammals manifests a closer adhesion to type than is observable in this part of the sku in any of the oviparous vertebrates, and it shows the necessity of extendin comparisons over the entire series, and not deducing the vertebrate arche type exclusively from those inferior forms: for although it may be upon th whole best retained in them, yet the modifications superinduced in subse viency to their exigences, and by which they diverge to that extent from th common plan, and, as a series of species, from the common vertebrate sten may affect a part which the conditions of existence of higher forms do no require to be so masked. The early ossification and large proportional siz of the hyoidean arch in the human embryo is very significant of its tru nature and importance, in relation to the archetypal vertebrate structur *i. e.* as being the hæmal complement of a primary segment of the skull.

Exogenous processes descend, like the pair from beneath the lower ce vical vertebræ of some birds, from the body of the parietal vertebra; bu the true transverse processes of this vertebra are the mastoids, which alwa articulate with a corner of the parietals.

The centrum and neurapophyses of the frontal segment retain their ord nary proportions, and the spine is again the element which, by its extren expansion and its modification in subserviency to the formation of the orbit chiefly masks the typical features of the neural arch. The parapophysis connate and reduced in size, and its vertebral relations with the pleurapo physis of its segment interrupted by the interposition of the diverging appe dage from the antecedent hæmal arch: the unusually expanded distal en of the same appendage also intervenes between the frontal pleur- and hæn apophyses; the pleurapophysis (28) being more atrophied in man than i most inferior mammals. The hæmapophysis and spine are on the oth hand much developed and modified as above described, for the business o mastication, though relatively shorter than in other mammals.

The compression and extension, both vertically and longitudinally, of th centrum (13), the compression and coalescence of the neurapophyses (14), bot with each other and the nasal capsules (18), and the corresponding proportio f the divided spine (15), mainly characterize the neural arch (N IV) of the erminal or nasal segment of the human skull. The early coalescence of each æmapophysis (21) with the corresponding half of the divided hæmal spine (22), nd the unusual expansion of the bones, especially the second (27), which iverge from the hæmapophysis, form the chief characteristics of the hæmal rch (H IV) of the nasal segment. The hæmapophysial portions of both the asal and frontal vertebræ are much less elongated than in most other nimals.

It may serve to test the accuracy of the general homologies here assigned o the bones of the human skull, if we notice the degree to which they have een subject to modification in connection with such determinations.

According to the general character of the vertebral elements in the rest of e frame, we should be prepared to expect that the hæmal arches would be ubject to a greater variety in respect of development and relative position their segments than the neural arches; and that in the latter the parts etermined as centrums and neurapophyses would retain more of the or- inary proportions of such parts in other segments or in other animals, than e peripherally situated spines. If new bones are added, we should expect find them in the relative position of appendages to the normal vertebral rches: or should these be homologous with similar superadditions in the kulls of lower animals, they will probably be the seat of more extensive anges of form, proportion and connections, than the elements of the verte- ral arches themselves.

Now if the reader will glance at fig. 25 and compare the bones forming e segments of the skull with those in figs. 24, 23, 22 and 5, he cannot but be ruck with the remarkable degree of uniformity in the dimensions of the ones 2, 6 and 10: no. 14 being the terminal neurapophysis, has been the seat f more variety; but the general steadiness of this series of bones in regard their dimensions and connections accords with the characters assigned to em, as neurapophyses, which are always the most constant and important the ossified vertebral elements.

The bones 1, 5, 9 and 13 equally conform in the kind and degree of their odifications with their determination as the bodies of the vertebræ.

The increasing capacity of the neural canal of the head, demanded for the dgment of the progressively expanded encephalon as the vertebral scale rises, chiefly acquired by the expansion of the bones, 3, 7, 11, which, being deter- ined as 'neural spines' in the fish, might be expected to be subject to greater eviations from their typical form and proportions than the more central d essential parts of the neural arches. The terminal neural spine, 15, is bject to still greater varieties in the range of species, as might also be ex- cted from its position. In one mammal, *e.g.* the porcupine, it is more panded than any of its succeeding homotypes in the cranium; in man its oportions are so much reduced as greatly to mask the homotypal relation. one mammal, *e.g.* the orang, the nasal spine is not only diminutive but ngle: in another mammal, *e.g.* the manatee, it is also diminutive but di- ded, and the halves completely separated by the intervention of part of the cceeding spine.

The abnormal conditions of the human skull give further illustration of the uth of these general homologies of the cranial bones, and reciprocally re- ive light from such determinations. In the case of idiots from defective owth or development of the brain, where the cavity of the cranium is re- ced to half or less than half its normal capacity, as *e.g.* in the skull described d figured in my 'Memoir on the Osteology of the Chimpanzee*,' it might

* Zoological Transactions, vol. i. p. 343, pl. 57 and 58.

have been expected from the anthropotomical ideas of the cranial bones,—according to which no one bone is deemed either more or less important than another in its essential nature, and where the squamosal is as little regarded in the light of a superadded or intercalary piece as the alisphenoid,—that all would be reduced in the same proportion in forming the parietes of the contracted brain-chamber. But this is by no means the case. In the instance above-cited the basioccipital and basisphenoid have been developed to their usual size, and the distance from the posterior boundary of the bony palate to the anterior border of the foramen magnum is as great as in any normal skull. The exoccipitals (condyloid portions of the occiput), the alisphenoids and the orbitosphenoids retain in like manner their full dimensions. The distance between the frontal and temporal bones is as great as in the average of fully developed Caucasian skulls, and is greater than in most of those from the Melanian race, in which the direct junction of the frontal with the temporal, as in the chimpanzee, is by no means rare. The contraction of the capacity of the brain-chamber is due chiefly to arrested development of the frontals, parietals, supraoccipital and squamosals. By the reduction of the supraoccipital and the retention of the centrums of the cranial vertebræ of their normal proportions, the foramen magnum becomes situated nearer the back part of the basis cranii than in the normal skull.

In a still smaller cranium of a female idiot, who reached the age of twenty-one years, which is preserved with the male idiot's skull above-mentioned in the anatomical museum of St. Bartholomew's Hospital, the contrast between the normal proportions of the basioccipital, basisphenoid, exoccipitals, alisphenoids and orbitosphenoids, on the one hand, and the reduced dimensions of the supraoccipital, parietals, frontals and squamosals on the other, is still more striking and significant of the true nature of those bones. The normal growth of the centrums, indeed, might be explained by the concomitant nearly normal size of the medulla oblongata, base of third ventricle and optic chiasma, in the brain of the same idiot: but it is not so obvious from the condition of the brain itself why the alisphenoid should not have shrunk in the same proportion as the parietals, frontals and squamosals. To the homologist, however, the recognised difference of subjectivity to modification presented by the neurapophyses, spines and diverging appendages of the typical segments, renders very intelligible the partial seats of arrested growth in the bones of these idiots' crania.

In reference to disease, also, one sees not why the alisphenoid should have a minor attraction for the morbid products deposited, or be less subject to the destructive actions excited, during syphilitic or mercurial disease, than the parietals, or the orbitosphenoids than the frontals, or the exoccipitals than the supraoccipital: yet it needs but to examine any series of such morbid skulls in our museums of pathology to be convinced that the variable and peripheral elements of the neural arches, viz. their expanded spines, are almost exclusively so affected: the frontal and parietal being the most common seats of the disease; the supraoccipital a less frequent one, concomitantly with its minor deviation from the typical standard of the element. I have yet seen no example in which either a cranio-vertebral centrum or neurapophysis was so affected; but the nasal bones are notoriously attacked.

It would be easy to multiply such instances of the new light—new eyes, so to speak,—with which human anatomy, normal and abnormal, is viewed, after the essential nature or general homology of the parts have been appreciated.

If the bones 4, 8, 12, fig. 5, have been correctly determined as the parapophyses of the cranial vertebræ, they might be expected to be subject in the ourse of adaptive modification to the loss of their individuality, and from utogenous elements to be reduced to the condition of exogenous processes. Now this is exactly what we trace in the series of vertebrate skulls; and we re further prepared to expect that the simplification of the segment forming ıe anterior extremity of the vertebral series will be in part effected by the ɔtal disappearance of its least important elements, the parapophyses. These re, in fact, absent in the nasal vertebra in all animals; they become conuent with the occipital vertebra in most reptiles and all warm-blooded aniıals; and in the latter, we find, with the exception of a few birds, that the arapophyses of the frontal vertebræ have likewise lost their individuality.

The first endoskeletal bones which plainly disappear from the skull in racing its modifications upwards from fishes are those which, in the present ertebral theory, have been referred to the category of diverging appendages; iz. the entopterygoid (fig. 5, 23), the operculars (*ib.* 34–37), and the branchioegals (*ib.* 44). The first bones that we discover to be plainly superadded ɔ those that remain after the above subtraction, in the skull of the reptiles, ɔr example, are, also, referable, in the present vertebral theory, to the same ariable and inconstant class of elements: they are the ectopterygoids (fig. 2, 24′), the malars (figs. 22 to 25, 26) and the squamosals (*ib.* 27); and are, ı general homology, diverging appendages of the palato-maxillary arch. They are subject to more inconstancy as to their existence than the more egular and normal elements of the skull: some reptiles, for example, have ıe malar and squamosal, whilst others want them; most reptiles have the ctopterygoid, but this, which is not present in fishes, is again taken away in ıe warm-blooded vertebrates. With reference to inconstancy of form and ɔnnections no bone of the cranium exceeds the squamosal, and it is precisely ıis distal element of the diverging appendage, which, through its inordinate evelopment, most masks the archetypal character of the human cranium compare 27, fig. 25, with 27, fig. 23).

Classification of Skull-bones.—A knowledge of the special homologies of ıe bones of the skull is essential to that of their general homology, and a knowdge of their general homology is indispensable to their natural classification.

Cuvier divides the bones of the head in all animals into bones of the *craium* and bones of the *face.*

The bones of the cranium are those of the cavity containing the brain: l the rest are bones of the face and contribute to form the cavities for the rgans of sight, smell and taste*. But these primary divisions do not inude the same bones in all animals: the nasal (fig. 5, 15) and vomer (*ib.* 13) e cranial bones in fishes, but not in mammals: the squamosal (fig. 25, 27) is cranial bone in mammals and not in birds or reptiles, &c. And this disepancy in the Cuvierian classification of cranial bones is due, not only to a on-appreciation of their essential nature, but partly to mistakes of special ɔmologies: thus the nasal is called ethmoid in the fish, and the squamosal called jugal in the bird.

In all anthropotomical classifications the bones of the *cranium* are reckoned ght in number: four single, viz.—

The frontal (fig. 25, 11);
The ethmoidal (*ib.* 14 and 18);
The sphenoidal (5, 6, 9, 10 and 21);
The occipital (1, 2 and 3): and
four in pairs, viz.—
The two parietal (7), and
The two temporal (8, 16, 27, 28 and 38).

* Leçons d'Anat. Comp. t. ii. (1837) p. 150.

The bones of the *face* are reckoned as fourteen in number, viz.—
The two malar (26);
The two maxillary (21, 22);
The two palatal (20);
The two nasal (15);
The two turbinal (19);
The vomer (13), and
The mandible (29–32).

The detached portion of the hyoid arch (40, 41) and its appendages (47), together with the whole of the scapular arch and its appendages, are excluded from the category of the bones of the head.

The natural classification of the bones of the human skull appears to me to be, first into those of
The Endo-skeleton,
The Splanchno-skeleton, and
The Exo-skeleton.

The primary division of the bones of the *endo-skeleton* is into the four segments, called
Occipital vertebra, N I, H I;
Parietal vertebra, N II, H II;
Frontal vertebra, N III, H III;
Nasal vertebra, N IV, H IV.

These are subdivided into the neural arches, called
Epencephalic arch (1, 2, 3);
Mesencephalic arch (5, 6, 7, 8);
Prosencephalic arch (9, 10, 11 and 12);
Rhinencephalic arch (13, 14, 15):
and into the hæmal arches and their appendages, called
Maxillary arch (20, 21 and 22) and appendages (24, 26, 27);
Mandibular arch (28, 29–32) (no appendage);
Hyoidean arch (38, 40, 41) and appendages (46);
Scapular arch (51 and 52) and appendages (53–58).

The bones of the *splanchno-skeleton*, are
The petrosal (16) and otosteals (16′)*;
The turbinals (18 and 19) and teeth. (The sclerotals retain their primitive histological condition as fibrous membrane.)

The bones of the *exo-skeleton*, are
The lacrymals (73).†

* These ossicles are described by most anthropotomists as parts of the 'temporal bone.' "Os temporum infantis magnopere ab osse temporum adulti differt; labyrinthi et ossiculorum auditûs fabrica absoluta est," says Soemmerring in the classical work before cited (t. i. p. 132). The signification of the differences between the fœtal and adult human temporal bone, which the great anthropotomist truly regarded as so remarkable, is made plain by anatomy; which shows the bone to be an assemblage of several essentially distinct ones, and at the same time exposes the character of that singularly heterogeneous assemblage and coalescence of osseous elements to meet the exigences of the peculiarly developed frame of man. What the 'ossicula auditûs' are, is a problem which still awaits careful additional research in the embryonic development of the hæmal arches of the cranium, for its satisfactory solution. The question is not, of course, whether they are dismemberments of the 'temporal bone,' since this has no real claim in any animal to an individual character; but whether the ossicles of the ear-drum in mammals are to be regarded, like the pedicle of the eye-ball in the plagiostomous fishes, as appendages to a sense-organ, and thereby as developments of the splanchno-skeleton; or whether they are, like the tympanic ring, modifications of the tympano-mandibular arch. The reasons are adduced in the Chapter on 'Special Homology' (p. 235) which have led me to view them as peculiar mammalian productions in relation to the exalted functions of a special organ of sense.

† The numerals refer to the bones so marked in the figures.

The course of coalescence reduces the epencephalic arch (fig. 25, N 1) to one bone, the scapular arch (H 1) to one bone (the arch is apparently completed by the connexion of an element (52′) not appertaining to the skull). The centrums (5, 9) and neurapophyses (6, 10) of the parietal and frontal vertebræ coalesce with each other and with the diverging appendages (24) of the maxillary arch to form one bone, the 'sphenoid' of anthropotomy, and this ultimately coalesces with the epencephalic arch and constitutes the 'os spheno-occipitale' of Soemmerring. The expanded halves of the parietal spine (7) remaining usually distinct are reckoned as two bones. The expanded halves of the frontal spine (11) usually coalescing together form a single bone. The halves of the nasal spine (13) rarely coalescing are counted as two bones. The mastoid (8) coalescing with the petrosal (16) and this with the tympanic (28), squamosal (27) and stylohyal (38), the whole is reckoned a single bone, which thus combines a parapophysis and pleurapophysis of one vertebra with a pleurapophysis of another and a diverging appendage of a third vertebra, and all these parts of the endo-skeleton with a sense-capsule belonging to the splanchno-skeleton: such is the heterogeneous compound character of the 'temporal bone' of anthropotomy. The neurapophyses of the nasal vertebra (14) coalesce with each other and with a considerable part of another ossified sense-capsule (18), to form the single bone called 'ethmoid.' The maxillary bone includes the superior maxillary (21) and premaxillary (22) of the lower animals. The hyoid bone includes the basihyal (41), with the ceratohyals (40) and the thyrohyals (46). The scapula includes both the pleurapophysis (51) and the hæmapophysis (52) of the occipito-hæmal arch. The signification of the separate points of ossification of the human fœtal skull is made plain by the foregoing applications of the ascertained general homologies of the bones of that part of the skeleton.

Objections to the Cranial vertebræ considered.—The latest and most formal objection to the fundamental idea in accordance with which I have attempted to work out the general homologies of the bones of the head, is also the most formidable in respect of the great and deserved eminence of the objector. In a manuscript left by Baron Cuvier, entitled, "Le crâne est-il une vertèbre ou un composé de trois ou quatre vertèbres?" appended to the posthumous edition of the 'Leçons d'Anatomie Comparée*,' he admits that "the analogy of the basilar and two condyloid parts of the occiput with the body and two halves of the annular part of the atlas is very appreciable. The basioccipital and the body of the atlas serve equally to support the myelon; the exoccipitals and the two halves of the ring of the atlas to cover it. The condyles are represented by the articular processes by which the atlas is joined to the dentata. The condyloid foramen, which gives passage to the nerve of the ninth pair, has some relation with the hole in the atlas which gives passage to the first cervical nerve and to the first bend of the vertebral artery. Some have also found a certain relation between the mastoid process, which in most animals appertains to the occipital bone, and the transverse process of the atlas and the other vertebræ; upon which it must be remarked that these relations are less in man, in some respects, than in the quadrupeds, since the atlas has commonly only a notch for the passage of the artery, and the mastoid belongs in man entirely to the petrosal"†. "We may even com-

* Tome ii. p. 710. (1837) par MM. F. G. Cuvier and Laurillard, who hold the arguments of their author to be conclusive. The criticism in the 'Histoire des Poissons,' t. i. p. 230, bears only upon the *à priori* cranio-vertebral theory of Geoffroy, and does not concern us here.

† "L'analogie de ces trois pièces, le basilaire et les deux condyloïdiens, avec les trois pièces de l'atlas, son corps et les deux moitiés de sa partie annulaire est très sensible. Le basilaire et le corps de l'atlas servent également à supporter la moëlle épinière; les condy-

pare," Cuvier says, "the supraoccipital to the spinous processes which in certain animals originate by special points of ossification and remain for some time distinct from the rest of the vertebra: nevertheless, there is already here a great difference of structure and function *." With regard to the points in which Cuvier is willing to admit an 'analogy' between the occiput and the atlas, he subjoins, agreeably with his idea of the law which governed such correspondences,—"These resemblances might naturally be expected in the part of the head placed at the extremity of the vertebral column, and the functions of which are, in fact, analogous to those of vertebræ, since it gives passage, like them, to the great neural axis †."

With regard to the feature of resemblance (quelque rapport) which some had seen between the mastoid process and a transverse process, Cuvier founds his objection to its application to the vertebral character of the occipital bone on a false homology. Concluding that the mastoid in man (fig. 25, 8) was homologous with the paroccipital in the hog (fig. 24, 4) ‡ and some other quadrupeds, he deems the determination of the paroccipital as the transverse process of the occipital vertebra to be invalidated by the fact that the 'mastoid' belongs, in man, not to the occipital but to the petrosal. There were cases, however, not unknown to the able Editors of the posthumous edition of the 'Leçons d'Anatomie Comparée,' where the true transverse processes of the occipital vertebra, though exogenous like those of the succeeding trunk-vertebræ in man, had become developed to an equal extent with such transverse processes; the abnormality of the human occipital thus repeating its normal condition in the quadruped. They however do not cite these instances, or notice the confusion by their author of the true mastoid with the paroccipital in reference to this his first objection to the vertebral homology of the occipital segment. But it might further have been remarked, in respect of the segment of the skull to which the mastoid really stands in parapophysial relation, that although the mastoid belongs in man to the petrosal in the sense of being anchylosed with it, it articulates with the parietal; and the persistence or obliteration of a primitive suture is too variable a phænomenon to determine to which of two bones a third connected with both essentially belongs. The constant existence of the paroccipital either as an autogenous element or an exogenous transverse process in all the oviparous vertebrate classes, its common existence in mammals, and occasional, though rare, development in man, establish that additional, though by no means essential vertebral character in the occipital segment, which

loïdiens et les deux moitiés de l'anneau de l'atlas à la couvrir. Les condyles sont représentés par les facettes articulaires au moyen desquelles l'atlas s'unit à l'axis. Le trou condylien qui laisse passer le nerf de la neuvième pair, a quelque rapport avec le trou de l'atlas qui laisse passer le premier nerf cervical, et la première courbure de l'artère vertébrale. On a aussi trouvé quelque rapport entre l'apophyse mastoïde qui, dans la plupart des animaux appartient à l'occipital, et l'apophyse transverse de l'atlas et des autres vertèbres; sur quoi il faut remarquer que ces rapports sont moindres dans l'homme à certains égards que dans les quadrupèdes, puisque l'atlas n'y a ordinairement qu'une échancrure pour le passage de l'artère et que l'apophyse mastoïde y'appartient entièrement au rocher."—*l. c.* p. 710.

* "On pourrait même comparer l'occipital supérieur aux apophyses épineuses qui, dans certains animaux, naissent par des points d'ossification particuliers, et restent quelque temps distincts du reste de la vertèbre; cependant il y aurait déjà ici une grande différence de structure et de fonction."—*l. c.* p. 711.

† "Ces resemblances étaient naturelles à attendre dans la partie de la tête placée à l'extrémité de la colonne vertébrale, et dont les fonctions sont en effet analogues à celles des vertèbres puisqu'elle laisse passer comme elles le grand tronc medullaire."—*l. c.* p. 711.

‡ Cuvier, *e. g.* describes this element as "L'apophyse mastoïde, qui est très-longue, très-pointue et toute de l'occipital," in his elaborate *Ossemens des Cochons*, Oss. Fossiles, t. ii pt. i. p. 117.

Cuvier seeks to obscure by the normal absence of its proper transverse processes in man, and the assumed transference of them to another part of the skull.

Cuvier in the next place objects to the comparison of the supraoccipital with the neural spine of a trunk-vertebra, "because of its vast difference of structure and function." He does not specify the nature of the difference: he admits that the neural spines have distinct centres of ossification in certain animals; and all will allow that, in most of the trunk-vertebræ of such, the neural canal is closed by the coadapted ends of the neurapophyses to which the spine articulates or becomes anchylosed: that therefore such spine does not directly cover the neural axis, but, retaining the shape signified by its name, performs exclusively the function in relation to muscular attachments. At first view the contrast seems conclusive against all homology between such mere intermuscular spine and the broad thin convex plate applied over the cerebellum and posterior cerebral lobes in man. And it must be confessed that the determination of their general homological relations could not have been satisfactorily demonstrated by the mere relations of the parts to the laminæ supporting them, in so limited a range of comparison. But, if we descend to fishes, we shall find the supraoccipital often equally excluded from the neural canal by the meeting of the exoccipitals beneath its base; we shall, also, see it still retaining the spinous figure, indicating its function in relation to muscular attachments to predominate over that in subserviency to the protection of the epencephalon. If we then ascend to the crocodile, we shall find the neural spine of the atlas to be one of those examples alluded to by Cuvier, where the ossification proceeds from an independent centre: and it not only thus manifests its essential character as an autogenous vertebral element, but maintains its permanent separation from the neurapophyses: and it further indicates the modifications of form to which the corresponding elements will be subject in the more expanded neural arches of the antecedent cranial segments by having already exchanged its compressed spinous for a depressed lamellar form. Here indeed Cuvier might not only have objected to recognise it as a vertebral spine by reason of its change of form and function, but also by its continuing a distinct bone, which is not the case with the expanded 'spine' of the mammalian occipital vertebra. But returning to the crocodile, we observe in the segment anterior to the atlas that both the form and connections of the supraoccipital (fig. 22, 3) are so closely similar to those of the neural spine of the atlas that the recognition of their serial homology is unavoidable; and we have a repetition of the same characters of the vertebral element in question in the small and undivided parietal (*ib.* 7). Now Cuvier makes no difficulty in admitting the 'occipital supérieur' in the crocodile to be the homologous bone with its more expanded namesake in the bird; or this with the still more expanded 'partie grande et mince de l'occipital' in mammals and man: he is also disposed to admit the special homology of the supraoccipital under all its variations of form and function in the above-cited air-breathing animals with the bone 3 in fishes, which he sometimes calls 'occipital supérieur,' sometimes 'interpariétal.' If then the special homology be admitted on the ground of the constancy of the connections of the part, with what show of reason can its general homology be rejected which forms the very basis or condition of the characters determinative of such admitted special homology? But Cuvier is not consistent with himself in his grounds of objection to the essential nature of the human supraoccipital as the neural spine of its segment; for he does not hesitate to call the atlas of the crocodile a vertebra, although its 'annular part' is closed above by a transverse plate* instead of by a vertical spine, of which, indeed, there remains hardly more vestige than is presented by the tubercle or rudiment of the spinous process in the supraoccipital of man. It must also be remembered, that the human supraoccipital does retain to a certain extent the same function in relation to the attachment of the proper vertebral muscles (*splenii capitis*, *complexi*, and the modified interspinales called '*recti capitis postici maj. et min.*) as the succeeding vertebral spines; and combines this with the same place of completing, as the key-stone, the neural arch; although by reason of the more voluminously developed segment of the neural axis protected by that arch the peripheral element is chiefly modified for the acquisition of the required increase of space.

Cuvier next proceeds to comment on Oken's endeavour to represent the basisphenoid and the two alisphenoids with the two parietals as forming a vertebra: and he admits that there is some analogy, though this is much more feeble than the differences. "The basisphenoid, having another function, takes on a different form from the basioccipital, especially above, by virtue of the posterior clinoid processes: and in the embryo it is composed not of a single nucleus, but of two†." With respect to the objection from the modification of form alluded to, it may be remarked that the same element in other vertebral segments of the body undergoes much greater change of shape; the centrums of the lower cervical vertebræ in many birds send down two processes as well-marked as the ascending ones called 'clinoid' in that of the parietal vertebra, not to speak of the 'soc de charrue' of the coccygeal vertebræ of the bird, for example, without any difficulty having been felt or expressed by Cuvier in their recognition as modified vertebral bodies, the more essential characters of their general homology being as plainly retained as in the case of the basisphenoid; in its relation, *e. g.* to the neurapophyses and the support of the mesencephalon. With regard to the objection from the two centres of development, if this be valid against the general homology of the basisphenoid (5, fig. 25) as a vertebral centrum, it equally tells against the body of the atlas (*c*), which, as Cuvier well knew, was ossified sometimes from two, and sometimes from three centres ‡. And I may further observe that, although Cuvier affirms the two ossific centres of the basisphenoid to retain for a long time between them simple cartilages, my observations bear out the accuracy of the remark of Kerkringius, (whose figures Cuvier cites,) touching the "dua ossicula distincta" (tab. xxxiv. fig. iii. *c*, *c*), viz. "quæ celerrimè in formam figuræ appositæ K coalescunt": and the figure of the coalesced rudiments of the basisphenoid given by Kerkringius closely resembles the bilobed rudiment of the vertebral centrums in the sacrum of the chick.

Cuvier next objects to the neurapophysial character of the alisphenoids, that the 'foramen ovale' is rarely a notch, more often a complete hole.

* "*Les vertèbres.* L'atlas est composé de six pièces, &c.—La première, *a*, est une lame transverse qui fait le dos de la partie annulaire. Elle n'a qu'une crête à peine sensible pour toute apophyse épineuse."—Ossemens Fossiles, t. v. pt. ii. p. 95.

† En avant du basilaire se trouve le corps du sphénoïde postérieur, aux côtés duquel adhèrent les deux ailes temporales ou grandes ailes. On a aussi cherché à représenter ces trois pièces comme formant une vertèbre avec les deux pariétaux. Il reste en effet encore quelque analogie, mais beaucoup plus faible, tandis que les différences deviennent plus fortes. Le corps du sphénoïde a bien l'air d'une répétition du basilaire, mais ayant une aûtre fonction il prend aussi une autre forme, surtout en dessus, au moyen des apophyses clinoïdes postérieures; et dans les premiers temps du fœtus il n'est pas composé d'un seul noyau, mais de deux, qui ont long-temps entre eux de simples cartilages."—*l. c.* p. 712.

‡ Leçons d'Anat. Comparée, t. i. (1836) p. 174. Meckel has figured the variety of three ossific centres in this element of the human atlas in the 1st vol. of his Archiv für die Physiologie, taf. vi. fig. 1.

'Now," he urges, "vertebræ properly so called give passage to the nerves only y the intervals that exist between them and the other vertebræ, and not by articular foramina*." Therefore the young anatomist must conclude that ıe dorsal vertebræ of the ox, the abdominal vertebræ of the lophius, and very other segment of the trunk whose neural arches are directly perforated y the spinal nerves, are to be rejected from the vertebral category!

It has been shown in the generalities on the corporal vertebræ (p. 95), that ıe neurapophyses in relation to the passage of their governing nerves may e either untouched, notched or perforated by them, without prejudice to ıeir neurapophysial character. Viewed in the entire series of vertebrata ıe cranial neurapophyses are more frequently perforated than notched, those f the trunk more frequently untouched or notched by the nerves in passing ırough their interspaces.

The penetration and sagacity of Cuvier nowhere shine forth more brightly ıan in his bold and true determination of the bone 6, fig. 5, in the cod-fish† : the homologue of the temporal wing of the sphenoid in the human skull. o any less-gifted comparative anatomist the relation would have been masked ; the coalescence of the homologous part in man, by its connections with the quamosal and frontal, and its comparatively small proportions under the ıise of a subordinate process; none of which characters exist in the ali-henoid of fishes: it still retains, however, in that class, as in man, its most sential connections in relation to the bones of its own segment and to the ain and nerves; and Cuvier availing himself of these in the determination its special homology, was little likely to be swayed by so unimportant a ıriety as the transmission of the characteristic nerve by a foramen instead by a notch. No sooner, however, has the time arrived and the call been unded for an advance to a higher generalization, which includes and ex-ains the minor proposition, than Cuvier interposes the least important fference of the alisphenoid to check the progress. It will be obvious to e anatomist that the foregoing explanation of the value of the nerve-tch or hole in the homological character of a neurapophysis has been lled forth by the weight of the name of the objector rather than by the rce of the objection.

(Cuvier directs his next argument against the vertebral character of the eural arch of the) parietal segment generally. "Its composition," he avers, s different from that of other vertebræ, since the ring (he had just before nied its annular form) would be composed of five pieces or even of six, inclu-ng the interparietal." Yet Cuvier does not hesitate, in his Article V., '*Les Ver-ıres*' (Ostéologie des Crocodiles)‡, to reckon as the first vertebra, the atlas twithstanding its composition of six pieces.

If, indeed, Cuvier had subscribed to Geoffroy's assertion, that "Nature repro-ces the same number of elements, in the same relations, in each vertebra, ly she varies indefinitely their form,"—his objection to the vertebral charac-of any given segment that might deviate from the assumed normal number pieces would have been intelligible. But even, then, he would not have en guided consistently by his own principle; for the objection founded on the supposed abnormal number of pieces in a cranial segment weighs

* "Ses ailes diffèrent beaucoup plus encore et des deux condyliens, et des deux pièces qui ment la partie annulaire des vertèbres. A' la vérité, le trou ovale n'est quelquefois qu'une ıancrure; mais le plus souvent il est entouré d'os, et par conséquent un vrai trou. Il en de même du trou rond toutes les fois qu'il est distinct du sphéno-orbitaire; or les vertè-s proprement dites ne laissent passer les nerfs que par les intervalles qui existent entre s et les autres vertèbres, et non par des trous particuliers."—*l. c.* p. 712.

† Règne Animal, 1817. pl. viii. fig. 2, *o*, p. 184.

‡ "L'atlas est composé de six pièces qui, à ce qu'il paroît, demeurent pendent toute la vie tinctes."—Ossemens Fossiles, t. v. pt. ii. p. 95.

not at all against the recognition of a corresponding segment of the trunk, though similarly composed.

In fact, throughout this attack upon the vertebral theory of the skull, it will be seen that it is based upon the *à priori* assumption that all the endo-skeletal segments of the trunk, however modified, are vertebræ, and all those situated in the head, are not vertebræ. The essential character of a vertebra is thus deduced from its position, not its composition. It needs only to compare any of Cuvier's objections to the vertebral character of the cranial segments, with the modifications of the corporal segments admitted by him to be vertebræ, previously enumerated in this Work (pp. 96–101), to see that the characters of the cranial vertebræ objected to by Cuvier differ in degree not in kind, and become valid arguments against the admittance of natural segments into the vertebral category, only when they happen to be situated at or near the commencement of the series.

It has been abundantly proved, I trust, that the idea of a natural segment (vertebra) of the endoskeleton, does not necessarily involve the presence of a particular number of pieces, or even a determinate and unchangeable arrangement of them. The great object of my present labour has been to deduce, by careful and sufficient observation of Nature, the relative value and constancy of the different vertebral elements, and to trace the kind and extent of their variations within the limits of a plain and obvious maintenance of a typical character.

In reference to the neural arch, the variation in the number and disposition of its parts, illustrated in the figures 1, 2, 3, 4, 18, 19, 20, 21, do not seem to me, nor will they I apprehend to any unbiassed anatomist, to obliterate the common typical character of that part of a vertebra. Those elements which are furthest from the centrum are the chief seat of the changes. If the reader will compare figure 2 with figure 19, he will see for example that the crown of the arch is formed by a single bone(7) in the crocodile, but by two bones (7, 7) in fish; nay, in most fishes the halves are even pushed apart by the interposition of a third bone. Yet the sagacity of Cuvier led him to determine the divaricated moieties of the divided parietal in such fishes to be the same (homologous) bone with the single parietal of the crocodile. With what consistency then, can the general homology of the segments be rejected, which suffer no other change in their composition than that resulting from the single or bifid character of the same bone in each? Is the single frontal of the human adult regarded as a distinct bone from the bifid frontal of the fœtus? If therefore, the neural arch of the parietal vertebra (mesencephalic arch) of the crocodile be free from the objection, raised by Cuvier to the vertebral character of the homologous arch in man, on the score of the number of its elements; neither can that objection be allowed to have any force when it rests upon the mere division in the human mesencephalic arch of the recognised homologue of the single spinous element in the crocodile.

In the sheep, the arch which encompasses the epencephalon is formed by only three elements, the neural spine resting upon the conjoined upper end of the neurapophyses. In the dog these elements are divaricated and the epencephalic arch is closed above by the neural spine. Now Cuvier does not allow this difference of arrangement of the latter element (3) to affect his recognition of the 'suroccipital' in both mammals; and, therefore, one is at a loss to discover the consistency of the ideas which would repudiate the general homology of the bones or of the entire arches which they surmount because, as Cuvier would say, "the composition of the arch is different, being of three pieces in the sheep and of four pieces in the dog." Yet this is precisely the kind of objection which he has directed against the mesencephalic arch, viz. because it may be composed of five or even six pieces, in certain nimals. In the fish, in fact,—by reason of the parietal parapophyses (8, 8) being subject to the same variation in their relative position to the other elements, which has been illustrated in respect of the neural spine in the epencephalic arch of the dog and sheep,—the mesencephalic arch is composed of seven pieces, or, including the interposed supraoccipital, of not less than eight bones. Yet even here we clearly and easily trace the kind and degree of modification to which the fundamental plan of the neural arch has been subject. The archetype is nowise obliterated: the general homologies of the modified elements are not less recognisable than their special homologies. The centrum and neurapophyses are the steadiest elements: the spine is not only subject to great diversity of size and shape, but to some variety of position, and, moreover, to be either single or bifid: the parapophyses have less range of variety in point of dimensions, but may be more or less interposed between spine and neurapophyses, or may become confluent with either element. Thus the epencephalic arch of the crocodile (fig. 18) differs essentially, in a Cuvierian sense, from that of the tortoise or the fish (fig. 1), because it is composed of four pieces in the first and of six pieces in the latter; the difference of composition merely depending, however, on the more exterior position and connation of the parapophyses, 4, 4, in the crocodile.

The independency of the parietal and frontal bones is next urged by Cuvier as militating against the idea that they complete a vertebral arch formed respectively by the alisphenoids and orbitosphenoids as the piers or haunches: and the more so, inasmuch as they are separated from those bones in some animals by the intercalation of the squamosals*. By parity of reason we must reject the general homology of the neural arch and spine of the atlas in the *Silurus* (Pl. I., fig. 3, *n a*), *Ephippus* and some other fishes, because that part of the vertebra is not only distinct, but uplifted and removed from the piers or base of the arch by the intercalation of the articular processes of the neural arches of the occiput and axis. According to Cuvier such separated atlantal arch must be regarded as a new bone, and the centrum ought therefore equally to be viewed as 'une pièce particulière qui a une destination particulière': but the general homology of vertebral elements may be determined not only by the irrelations to their own segment, but by those which they maintain with their less modified homotypes in contiguous segments.

The centrum of the atlas in the *Ephippus* directly sustains other neurapophyses than its own, and so far has a new or particular function; but, since it continues to unite the centrum of the axis with that of the occiput, we still regard it as their homotype, and as standing in the relation of the centrum to its uplifted and shifted neurapophyses. So, likewise, although these elements now aid in strengthening the joint between the zygapophyses of the neural arches of the occiput and axis, and thus perform a new and very peculiar function, their relation to these and other neural arches in the series of vertebræ renders it impossible to overlook the serial homology of the separated 'laminæ' of the atlas and that of its spine with the other and larger vertebral laminæ and spines.

* "Dans tous les cas, on ne pourrait regarder cette vertèbre comme annulaire, ni supposer que les pariétaux en forment le complément; d'une part, ce serait une composition différente de celle des autres vertèbres, puisque l'anneau serait formé de cinque pièces et même de six, en comptant l'inter-pariétal; de l'autre, il arrive dans plusieurs animaux que les ailes temporales du sphénoïde n'atteignent pas au pariétal, parceque le temporal va toucher au dessus d'elles, soit au frontal soit au sphénoïde antérieur. Ainsi les pariétaux sont des pièces indépendantes du sphénoïde postérieur, des pièces particulières qui ont une destination particulière, celle de servir de bouclier à la partie moyenne et postérieure des hémisphères, tout comme les grandes ailes ont celle de servir de support aux lobes moyens dans lesquels ces hémisphères se terminent vers le bas."—*l. c.* p. 713.

The new functions which the uplifted and independent spines of the parietal and frontal vertebræ perform in man and many mammals are, with respect to the parietal bones, to shield the upper surface of the middle and posterior parts of the cerebral hemispheres, whilst the frontal is confined to covering the anterior lobes of the same hemispheres.

Hereupon it may be asked whether such relations and offices are the rule or only the exception; and, if the latter, whether it occurs in the lowest or the highest of the vertebrate series; whether in that class where the archetypal arrangement of parts is most, or in that in which it is least departed from? All these considerations are felt to be indispensable by the homologist in quest of the true signification of the parts of the animal frame, before drawing his conclusions from the first modification that may present itself. They are neglected by Cuvier in the objection to the vertebral character of Oken's 'kiefer-wirbel,' founded upon the relations which the parietal bones present to the encephalon in the mammalian class. Yet the more normal relations of those bones, both to the encephalon and to the alisphenoids, seem to have been present to the mind of Cuvier, and to have been duly appreciated by him when he defined, in 1817, the second cranial cincture as constituted by the parietals and sphenoid*.

With regard then to the first of Cuvier's arguments for viewing the human and mammalian parietals as 'des pièces particulières qui ont une destination particulière,' viz. that they are separated from the alisphenoids by the temporal bones. If we commence our consideration of it by the question, whether this separation be the rule or the exception, the reply which Nature sanctions will be that they are not so separated in any of the three great classes of oviparous vertebrata, nor in the majority of mammalia, nor even, as a general rule, in man himself. With regard to the second objection founded on the interposition of the enormously and backwardly developed prosencephalon between the mesencephalic spines (fig. 25, 7) and the mesencephalic segment of the brain, to which the parietal vertebra essentially relates,—its value will depend on the choice made by the homologist between the function of the parietals as immediate shields to the optic lobes (mesencephalon) in the cold-blooded classes, and their function as mediate ones through the interposed mass of the hemispheres (prosencephalon) in the warm-blooded classes, as that which best manifests adhesion to the ideal archetype. What to me has ever appeared one of the most beautiful and marvellous instances of the harmony and simplicity of means by which the One great Cause of all organization has effected every requisite arrangement under every variety of development, is the fact, that the protection of the enormous cerebrum peculiar to the higher mammals has not been provided for by new bones—by bones, *e. g.* developed from centres so numerous or so situated as to render any determination of their homologies as vague and unsatisfactory as would result from the attempt to determine those of the dermal ossifications upon the head of the sturgeon in reference to the endoskeletal epicranial bones in fishes and reptiles. We might well have expected, had conformity to type not been a recognizable principle in the scheme of organized beings, to have had so many 'particular bony pieces' and so situated in the expanded human cranium as would have baffled all our endeavours to reduce them to the type of the epicranial bones of the reptile or fish. Yet the researches of the great comparative anatomists of the present century, and more especially those of Cuvier himself, have proved that there is no such difficulty: and a glance at the Table of Special Homologies, No. 1, will show that the bones (3, 7, 11) most modified in relation to the expanded cerebrum and cerebellum of man and mammals are

* Règne Animal, i. p. 73.

precisely those of which the determination has been easiest, and respecting the names and nature of which there has been the least discrepancy of opinion. It is with pain and a reluctance, which only the cause of truth has overcome, that I am compelled to notice the inconsistencies into which the great Cuvier fell, when his judgement became warped by prejudices against a theory, extravagantly and, perhaps, irritatingly, contended for by a contemporary and rival anatomist. After having established by the clearest evidence and soundest reasoning in his great and immortal works that the bones (7) in the fish (figs. 2 and 5) and reptiles (figs. 9, 10, 13, 19, 22) were homologous with those in birds (7, figs. 8 and 23), mammals (7, figs. 12 and 24), and even in man (7, figs. 11 and 25); and, after contending that they ought to bear the same name—under which, indeed, we find him describing them in the 'Leçons d'Anatomie Comparée' from man down to the fish—Cuvier comes at last to declare that, in those animals in which they are separated from the alisphenoids and mesencephalon, they are "particular pieces which have a particular destination!"

The relation of the mastoids (8, 8), as parapophyses, to the parietal or sphenoidal vertebra not having been detected in Cuvier's time, he supposes that the pterygoids, in the system which makes a vertebra of the sphenoid, can be compared to nothing else than the transverse processes of such. As, according to my views, they are recognizable in General Homology as quite distinct elements of another cranial vertebra, the arguments which Cuvier advances in disproof of what he thought they must be called, do not concern the subject of the present Report. The inferior exogenous processes, indeed, of the basisphenoid in mammals are not unlike those developed from the under surface of the centrum of the atlas in *Sudis gigas*, or from some of the cervical centrums in birds. The argument founded by Cuvier on the autogenous development of the true pterygoid (figs. 24 and 25, 24) would weigh little against its parapophysial nature, if other characters concurred to prove it a 'parapophysis;' but its connections and position show it to be a 'diverging appendage.'

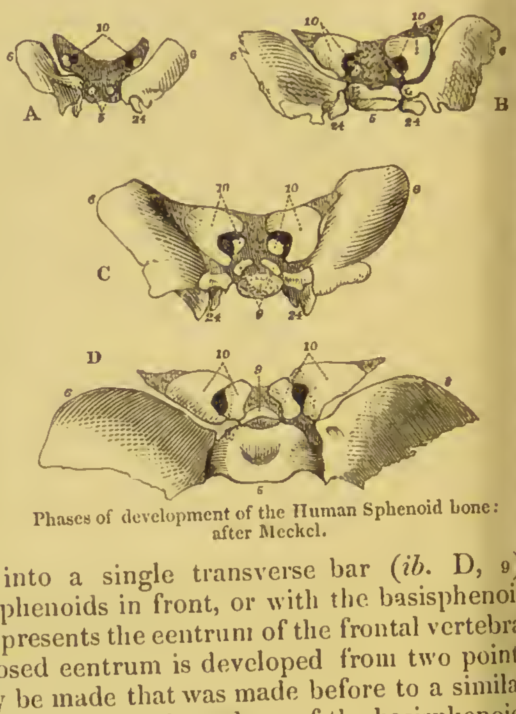
With respect to the anterior sphenoid, Cuvier affirms that its composition is totally different from that of the posterior sphenoid and occipital, and from that of any vertebra. By the term 'sphénoïde antérieure' is meant the coalesced presphenoid and orbitosphenoids (figs. 24 and 25, 9 and 10); and the two bones referred to in the comparison signify, the one, the basi- and alisphenoids (*ib.* 5 and 6), and the other the basi- and ex-occipitals (*ib.* 1 and 2). With respect to the bone 9 and 10, Cuvier remarks that it is never, in mammals, formed of three pieces, but only of two; and that these are properly the rings for the optic nerves, which in course of time approximate and coalesce with each other: but so long as the median suture divides them, no distinct or third bony nucleus is developed in the intervening cartilage*.

Since, however, we see that the homologues (recognised as such by Cuvier) of the orbitosphenoids are something more than rings surrounding the optic nerves in the bird (figs. 8 and 23, 10) and crocodile (figs. 9 and 22, 8)—that they are merely notched by the optic nerves, and are chiefly developed in

* "L'on a voulu aussi considérer le sphénoïde antérieur comme une vertèbre dont les [...]ntaux complèteraient la partie annulaire, et où la position du trou sphéno-orbitaire entre [les] deux sphénoïdes repondrait assez aux trous inter-vertébraux ordinaires. Mais la composi[t]ion du sphénoïde antérieur lui-même est toute différente de celle des deux os, dont nous [av]ons parlé avant lui, et de celle d'aucune vertèbre. Il n'est jamais, dans les mammifères, [for]mé de trois pièces, mais seulement de deux; ce sont proprement des anneaux osseux pour [les] nerfs optiques, qui par suite du temps se rapprochent et se soudent entre eux; la suture [est] toujours au milieu, et tant que l'ossification n'est pas complète, il n'y a entre les deux [an]neaux que du cartilage, dans lequel il ne se forme pas de troisième noyau."—*l. c.* p. 714.

neurapophysial relation to the sides of the prosencephalon,—we are led to carry our inquiries into an earlier period of their development than that adduced by Cuvier, as contravening their vertebral characters. Cuvier cites the figure 2, in pl. xxxv. of the 'Osteogenia Fœtuum' of Kerkringius, as evidence of his statement of the developmental characters of the 'sphénoïde antérieur." That figure, however, exhibits the condition of the bone, when, although the median suture remains, each orbital ala has become anchylosed with the posterior sphenoid, and is likewise directly perforated by the optic nerve. The gelatinous cells of the anterior extremity of the notochord very early retrograde to the basiocipital region of the basis cranii, and the notochordal capsule alone is continued to the anterior extremity of the basis. This is converted into cartilage, and the osseous particles which ultimately constitute the anterior sphenoid are deposited as follows: first a centre or nucleus appears, in each orbital ala, external to the hole by which the optic nerve passes through the primitive cartilage (fig. 26, A, 10); soon after a second nucleus (*ib.* B, 10) is established at the inner or mesial side of each optic foramen: these centres form the foundation of the neurapophyses or orbitosphenoids, and ultimately coalesce around the optic nerve, as Kerkringius has depicted. But a third pair of ossific centres (*ib.* C, 9) is established behind the optic foramina between these and the baispshenoid (5).

Fig. 26.



Phases of development of the Human Sphenoid bone: after Meckel.

This third pair unite together into a single transverse bar (*ib.* D, 9) before coalescing with the orbitosphenoids in front, or with the basisphenoi behind, and that bar transitorily represents the centrum of the frontal vertebra To the objection that such supposed centrum is developed from two point instead of one, the same reply may be made that was made before to a simila objection raised by Cuvier against the general homology of the basisphenoic which objection, as was then shown, would be equally valid against the uni versally admitted homology of the body or centrum of the atlas.

The frontal neurapophyses manifest in their development, each from tw centres (fig. 26, B, C, 10), a transitory mark of vegetative repetition analogou to that which permanently characterizes the neurapophyses of the trunk-verte bræ in the sturgeon and, perhaps, the frontal neurapophyses themselves i the fishes with the bone 9′, fig. 5, Pl. I.

Thus the evidence of development, when complete, tells for, rather tha against the serial homology of the 'sphénoïde antérieur' of Cuvier with th centrum and the neurapophyses of other vertebræ; and the more obvious an important characters of relative position to the other bones of their own seg ment, and to their homotypes in the contiguous segments, as well as to proser cephalic segment and characteristic nerves,—which characters have serve to determine the special homologies of the coalesced bones in question (9, 10 from man down to the fish,—concur with the developmental characters i establishing the general homology of the presphenoid as centrum and of th orbitosphenoids as neurapophyses of the frontal vertebra.

Cuvier affirms, however, in support of his argument, that, although the orbitosphenoids are never separated from the frontals, as the alisphenoids are from the parietals, in the mammalia, they are almost always separated from the frontals in the other classes, so that the vertebral ring is again interrupted *. But, were even the frontals commonly uplifted above the orbitosphenoids in birds, reptiles and fishes, which does not accord with my experience, the objection, on that score, to regarding them as 'neural spines,' would as little apply, as it does to the universally recognised general homology of the separated and uplifted neural arch of the first vertebra of the trunk of the *Silurus* (Pl. I, fig. 3), *Ephippus* and some other fishes.

Cuvier finally regards the connection of the frontals with the prefrontals, which he calls 'ethmoid' in mammals, 'l'enchâssement de l'ethmoïde,' as a function quite remote from any of a vertebral character, "relative à toute autre chose." This objection only shows the necessity of a right appreciation of special homologies, in order to form a true judgement respecting general homology; and, with respect to the 'ethmoïde,' I must refer to the section on the prefrontals in the chapter on 'Special Homology (p. 46). If the arguments there adduced be held to prove the crista galli and cribriform plate in the human skull to be the homologues of portions of the coalesced prefrontals and olfactory capsules, we may next remark that these portions are not merely wedged between the orbital plates of the frontal, but articulate behind by a persistent suture with the orbitosphenoids. As neurapophyses, the coalesced prefrontals of the terminal vertebra of the skull thus articulate with their next succeeding homotypes; and, by virtue of the excessive development of the spine of the frontal vertebra, as well as from their being contracted and drawn backward in the human skull, they articulate with such spine (the frontal) as well as with that of their own proper segment (the nasals). But, in the crocodile (fig. 9), we have seen a similar relation manifested not only by the more normal neurapophyses (14) of the nasal vertebra, but likewise by those (10) of the frontal, those (6) of the parietal, and those (2) of the occipital vertebra.

All the objections raised by Cuvier to the general homology of the cranial bones as modified vertebral elements, equally apply to elements of vertebræ of the trunk, which Cuvier himself has admitted to be vertebræ, notwithstanding such modifications. The repetition of the perforated character of the human alisphenoid and orbitosphenoid in the neurapophyses of the trunk-vertebræ of many inferior animals, requires only a passing notice. The flattening, expansion and sutural union of the human supraoccipital, parietal and frontal bones, are matched by the neural spines in the carapace of the tortoise. If the basioccipital, basisphenoid and presphenoid are broad and flat, instead of cylindrical, so likewise are the bodies of the sacral vertebræ in the broad-bodied megatherioids and in many birds. If the basioccipital and basisphenoid are lengthened out and firmly united together by deeply indented sutural surfaces in most fishes, so likewise are the bodies of the four anterior vertebræ of the trunk in the pipe-fish (*Fistularia*, Pl. I., fig. 6). If the basisphenoid and presphenoid be developed each from two ossific centres, as in man, so likewise may the body of the human atlas be ossified; and even should the moieties of that centrum not coalesce at the median plane, they

* "Ce que j'ai dit des pariétaux s'applique aux frontaux, considérés comme compléments du sphénoïde antérieur; leur fonction est relative à toute autre chose, à la protection des lobes antérieurs du cerveau et à l'enchâssement de l'ethmoïde; et quoique le sphénoïde antérieur ne soit jamais séparé dans les mammifères comme le postérieur l'est souvent des pariétaux, il l'est presque toujours dans les autres classes, en sorte qu'alors l'anneau vertébral serait aussi interrompu."—*l. c.* p. 714.

would nevertheless still retain their essential characters as divisions of a single vertebral element: just as does the vomer in the salamanders, salamandroid fishes and serpents, which begins to be developed from two lateral points, like the body of the human atlas occasionally, without the development ending, as it always does in such atlas, by confluence of the resulting halves. It would be more reasonable to repudiate the general homology of the body of a whale's dorsal vertebra with the centrum of the typical vertebra, because it consists of three pieces set end to end, than to deny the general homology of the vomer because it may consist of two pieces set side by side, or that of the anterior trunk-vertebræ of the silurus because they consist of two pieces set one upon the other (Pl. I., fig. 3, *c a*, *c a*, *e x*, &c.). These are examples of a principle of variation which Cuvier never permitted to blind his perception of the special homology of certain bones, the mandibular ramus, for example; though vegetative or teleological subdivision is carried out to a much greater extreme there than in any vertebral centrum; unless, indeed, the number of points from which the whale's vomer be ossified may equal those in the crocodile's lower jaw. But if the differences in this developmental character, viz. of ossification from a single ossific point as in the vomer of the cod, or from two points as in that of the lepidosteus, or from three or more points as in the human vomer, interpose no obstacle to the determination of the special homology of the bone 13 from man to fish, it can as little avai as an argument against its general homology, which is determined not by the development of the vomer but by its relations to the other constituents of the segment of the skeleton to which it naturally belongs.

The great difficulty which the anthropotomist may naturally experience in forming an idea of the vomer as the body of a vertebra, will arise from it extremely modified form in the human subject: but he must bear in mind that it is an extreme part, the last of its series counted forwards; and if he should desire some higher and better established authority than the presen Work before yielding assent to the vertebral character of the bone, unde its characteristic 'ploughshare' mask in man, I know no name more influen tial than that of Cuvier himself, in regard to the equally and similarly modi fied centrum at the opposite end of the vertebral series in the bird. Fo although the mask of coalescence is superadded to that of strangeness o shape in the bone which Cuvier there compares to a ploughshare [vomer, o 'soc de charrue'], the great anatomist and cautious generalizer does not hesi tate to affirm that it is "composed of many vertebræ" (see *ante*, p. 95).

It may, perhaps, be said that the coccygeal vomer must be vertebral in it nature because it is situated in the tail; but the 'petitio principii' in thi argument will be transparent, if we transpose the locality, and say that 'th cranial vomer must be vertebral in its nature because it is placed in th head.' For what are 'head,' 'tail,' 'thorax,' or 'pelvis,' but so many di versely modified portions of a great segmental whole? These localities do no determine the nature of the segments composing them; such knowledge ca only be acquired by a study of the composition of the segments; and it is th modifications of the segments that determine the nature of the localities o divisions of the endoskeleton, to which such special names as 'head,' 'tho rax,' &c. are applied.

Yet Cuvier himself, perhaps, little suspected how much his ideas of th essential nature of a segment of the endoskeleton were governed by the pa of the body in which it happened to be placed. Whenever the young ana tomist finds a difficulty from the peculiar form or development, divisio or coalescence, of a cranial bone, in recognising or admitting its vertebr character, let him compare the results of his own observations with those summed up in pp. 96–101, and see whether the same kind of modification may not be repeated in the homologous element of a vertebra of the trunk in one or other of the species of vertebrate animals.

The latest direct objection to the cranio-vertebral system is from the pen of the celebrated ichthyotomist of Neuchatel. M. Agassiz represents the current ideas respecting this system at the period when he published his objections to it, in the following graphic passage of his invaluable and splendid work:—"It was M. Oken who had printed the first programme on the signification of the bones of the skull. The new doctrine which he set forth was received with extreme enthusiasm in Germany by the school of Naturalists called 'Natur-philosopher.' The author at that time required three cranial vertebræ, and the basioccipital, the sphenoid and the ethmoid were viewed as the central parts of these cranial vertebræ. Upon these pretended bodies of vertebræ were raised the arches enveloping the central parts of the nervous system (our 'protective plates'); whilst to the opposite side were attached the inferior pieces which should form the vegetative arch destined to embrace the intestinal canal and the great vessel (the 'facial arches' of which we shall presently speak). It would be tedious to enumerate here the changes which each author has rung upon this theme in modifying it agreeably with his notions. These contented themselves with the number admitted by Oken; those raised the number of cranial vertebræ to four, six, seven, or even more: some saw nothing but ribs in the branchial arches and jaws; others took the latter for limbs of the head, analogous to arms and legs. If they could not agree about the number of the vertebræ, still less were they at one in regard to the part assigned to each bone. The most bizarre nomenclatures have been proposed by different authors who thus sought to generalize their ideas. Some have gone so far as to pretend that the vertebræ of the head were as complete as the vertebræ of the trunk, and by means of dismemberments, with divers separations and combinations they have reduced all the forms of skull to vertebræ, assuming that the number of pieces was invariable for every form of skull, and that all vertebrate animals, whatever their definitive organization, bore, in their respective crania, the same number of points of ossification *."

And thus it is that a great truth in nature has been endeavoured, and

* "C'est M. Oken qui fit imprimer le premier programme sur la signification des os du crâne. La nouvelle doctrine qu'il exposait fut accueillie en Allemagne avec un enthousiasme extrême par l'école des philosophes de la nature. L'auteur postulait alors trois vertèbres au crâne, et l'occipital basilaire, le sphénoide et l'ethmoide étaient envisagés comme les parties centrales de ces vertèbres craniennes. Sur ces prétendus corps de vertèbres s'élevaient les arcs enveloppant les parties centrales du système nerveux (nos plaques protectrices); tandis que du côté opposé étaient attachées des pièces inférieures qui devaient former l'arc végétatif destiné à embrasser le canal intestinal et les gros vaisseaux (les arcs de la face dont nous traiterons plus tard). Il serait trop long d'énumerer ici les changements que chaque auteur apporta à ce travail en le modifiant à sa manière. Les uns se contentèrent du nombre admis par Oken, les autres élevèrent le nombre des vertèbres craniennes jusqu'à quatre, six, sept et même plus; les uns voulurent voir des côtes dans les arcs branchiaux et les mâchoires; les autres prirent ces dernières pour des membres de la tête, analogues aux bras et aux jambes. Si l'on n'était pas d'accord sur le nombre des vertèbres on l'était encore moins sur le rôle qu'on assignait à chaque os. Les nomenclatures les plus bizarres ont été proposées par les différens auteurs, qui cherchaient ainsi à généraliser leurs idées. On alla jusqu'à prétendre que les vertèbres de la tête étaient aussi complètes que les vertèbres du tronc, et au moyen de démembremens, de séparations et de combinaisons diverses, on ramena toutes les formes du crâne à des vertèbres, en admettant que le nombre des pièces etait invariablement fixé pour toutes les têtes; et que tous les vertébrés, quelle que soit d'ailleurs leur organisation définitive, portaient dans leur tête le même nombre de points d'ossifications."—Recherches sur les Poissons Fossiles, t. i. (1813), p. 125.

too successfully in regard to the rising generation of anatomists, to be obscured. Ideas and statements are misquoted, unintentionally, doubtless, and through neglect of reference to the original work (as in the citation of the bones representing the bodies of the cranial vertebræ in the Okenian theory); or they are misunderstood (as where the arches, neurapophyses or 'bogentheile,' composed as Oken truly said by the alisphenoids and orbitosphenoids are held to be synonymous with the 'plaques protectrices' of M. Vogt): the most extreme and least defensible views are selected out of each tentative step in the inquiry, and are clubbed together to represent the general result, which is of course dismissed with as sweeping a condemnation. The specific objections raised by Cuvier are deemed well-founded and unassailable; and to these M. Agassiz adds the following. Assuming that, "the formation of vertebræ presupposes as a first condition the existence of a notochord*;" and, arguing upon this basis, and with a belief that the cephalic extension of the 'chorda dorsalis' as it is permanently manifested in the *Branchiostoma* is not so great in the embryos of other and higher fishes, but is arrested at the region of the alisphenoid from the commencement of its development, M. Agassiz concludes:—"Now, the application of this principle to the composition of the skull demonstrates at once that there exists *but one cranial vertebra, the occipital vertebra*, and that the rest of the skull is foreign to the vertebral system†."

At the period of development described and figured by M. Vogt in the embryo of the *Coregonus*, which period M. Agassiz conceives to represent the very earliest condition of the anterior extremity of the notochord, the pointed extremity of the gelatinous central cells of this part terminates at the posterior boundary of the hypophysial space: but the peripheral capsule of the notochord extends over that space and forwards to the obtuse anterior extremity of the embryonal 'basis cranii': and it is in the expanded aponeurosis, directly continued from the chorda along the basis cranii, that the thin stratum of cartilage cells are developed, arching along the sides of the hypophysial space, from which the ossification of the basisphenoid, presphenoid and vomer proceeds ‡.

The superaddition or the later continuation of the cylindrical gelatinous 'chorda' in the aponeurotic basis of the cartilaginous and osseous growths of the vertebral centres in the trunk, seems to relate chiefly to their more or less cylindrical form in that region: the notochord regulates, as a mould, the course of ossification, disappearing by absorption as the bony lamellæ of the vertebral bodies encroach upon it in their centripetal progress: the notochord plays an important part also in the establishment of the elastic jelly-filled capsular joints in the back-bone of fishes; and therefore it might well be dispensed with, or be early and rapidly removed, in the development of the flattened, expanded and anchylosed or immoveably articulated bodies of the cranial vertebræ. And, besides, the notochord is immediately concerned in the development of only one of the elements of the typical segment of the endoskeleton. It is obviously, therefore, an unwarrantable and erroneous application of a developmental character, to conclude, from a modification of this one character in respect of a single element, the 'centrum,' that every other character establishing the general homology of such element, as

* "La formation des vertèbres suppose, comme première condition, l'existence d'une 'corde dorsale.'"—*Op. cit.* tom. i. p. 127, livr. xviii. (1843.)

† "Or, l'application de ce principe à la composition de la tête nous montre d'entrée qu'il n'existe *qu'une seule vertèbre crânienne, la vertèbre occipitale*, et que le reste de la tête est étranger au système vertébrale."—*Ib.* p. 127.

‡ Hunterian Lectures on Vertebrata, 1846, p. 71.

ell as every character determining that of the surrounding vertebral elements, re to be nullified and set aside! M. Agassiz, moreover, seems not to have ıspected that the notochord may have other and more immediate and importut functions than even those relating to the vertebral column. The peculiar lective attraction of its component cells for the gelatinous principle may be esential to the due operation of those neighbouring cells which form the basis of ıe neural axis, and which as exclusively assimilate the albuminous principle: nd this reciprocal antagonism in the selection of particular proximate prin-iples from the common primitive blastema may explain the contemporaneous rigin of notochord and myelon in the embryonic trace, when all development as yet the work of cell-assimilation and metamorphosis, without any supply om a vascular system, this being a later formation in the building up of the rganic machinery. By confining, however, his views of the notochord to one f its functions in relation to a single vertebral element, and by extending his onclusions from this to the entire vertebra, M. Agassiz, though recognising ıore absolutely than Cuvier, the vertebral character of the neural arch of ıe occipital segment, concludes that Nature discards that type in the conormation of the bony cinctures that precede it and which successively girt ıe mesencephalon, prosencephalon and rhinencephalon.

Premising a gratuitous explanation of the hypothetical absence of the bodies f the cranial vertebræ (Poissons Fossiles, t. i. p. 128), M. Agassiz asks, Ainsi, que seraient dans cette hypothèse, le sphénoide principal, les grandes les du sphénoide, et l'éthmoide, qui forment pourtant le plancher de la ıvité cérébrale?—Des apophyses?—Mais, les apophyses ne protègent les entres nerveux que du côté et d'en haut?—Des corps des vertèbres?—Iais ils se sont formés sans le concours de la corde dorsale; ils ne peuvent onc pas être des corps des vertèbres." (*Ib.* p. 129.) To this it may be eplied, first that the bodies of the cranial vertebræ are not absent; they re represented, as above explained, by their cortical portions in the vomer ig. 5, 13), presphenoid (*ib.* 9) and basisphenoid (*ib.* 5), and by both cortical ıd central portions in the basioccipital (*ib.* 1): nay, the central part of the ıdy of the frontal vertebra is represented in some fishes by the entosphenoid *b.* 9′), which remains distinct from the cortical part below, as does the central ırt of the body of the atlas in the siluroid fish. If it were true, indeed, at the entosphenoid was pierced by the canals transmitting the olfacry nerves*, Bojanus' idea of its general homology as the centrum of the ertebra optica' must be abandoned. But the parts called 'olfactory erves' by M. Agassiz, pass from the prosencephalic to the rhinencephalic ompartments of the cranium not merely above the bone called 'cranial hmoid' by the same author, but, also, through the upper part of the interace between the bones (orbitosphenoids) which the entosphenoid (9′) stains: and the true olfactory nerves perforate the neurapophyses (14) hich Bojanus called 'ethmoid' and which Cuvier and M. Agassiz have rmed 'frontaux antérieurs' (see *ante*, pp. 46–58). The alisphenoids, being tched or perforated by their proper intervertebral nerves, are 'apophyses' eurapophyses), and accordingly do protect the sides of their proper nervous ntre, the mesencephalon. The central jelly-cells of the notochord appear to withdrawn into the occipital region before ossification of the basisphenoid mmences, and that modified vertebral body is therefore developed at the pense of the fibrous sheath of the notochord, and is represented by its ortical' part only. But its general homology is determined by its con-

* M. Agassiz has described this bone under the name of 'éthmoide crânien' as "un os pair, court, de forme presque carré dans lequel sont percés les canaux servant aux nerfs actifs."—Recherches sur les Poissons Fossiles, t. i. p. 120.

nections with the basioccipital (admitted by Agassiz to be a vertebral body) behind, and with the alisphenoids above.

In many fishes the basisphenoid unites with the basioccipital by a deeply indented sutural surface, like that which unites together the elongated bodies of the anterior trunk-vertebræ in the *Fistularia*. In mammals the basioccipital and basisphenoid join each other by flat surfaces, also like the bodies of the trunk-vertebræ, until the period when, in most of the class, the joint is obliterated by anchylosis. These and similar repetitions of class-characters of vertebral elements in the regions of the head and trunk are not so wholly devoid of signification, as they must seem to be to the opponents of the cranio-vertebral theory.

In his new and elaborate classification of the bones of the skull of fishes, M. Agassiz divides them primarily, like Cuvier, into bones of the *cranium*, or 'box which envelopes the brain and the organs of sense': and into bones of the *face*, 'which is composed of the moveable pieces subservient to nutrition and respiration' (*l. c.* p. 110).

This division is open to the objection that the bony or cartilaginous capsules which immediately envelope the organs of sense are always originally, and most of them permanently, separate from the box or capsule that envelopes the brain. The independent character of the ear-capsules, for example, is manifest on their first appearance in the ammocete; and, although they subsequently lose their distinctive features by the accumulation of cartilage-cells around them in which the foundations of the neurapophyses and parapophyses, contributing to the otocrane, are laid, one centre of ossification is commonly established, even in fishes, in special relation to the immediate protection of the vascular and nervous parts of the labyrinth.

As to the proper bony envelope of the eye, M. Agassiz does not enumerate it amongst the cranial bones of fishes: but admits into that series only the accessory protecting pieces which form the orbit; or rather only those that at the same time form the brain-case: for, the suborbitals, the entopterygoids and palatines are placed amongst the 'facial' bones: whilst the supraorbitals are transferred to another category of osseous pieces, the natural system here prevailing over the artificial one.

Subjoined* is an outline of the arrangement of the two primary classes of 'cranial' and 'facial' bones, founded upon the embryological researches of

* CRANIAL BONES. (OS CRANIENS.)

A. EMBRYONIC BASIS (*'BASE EMBRYONALE,'* Vogt).

a. Nuchal plate (*'Plaque nuchale,'* V.). Basioccipital, Exoccipitals, Paroccipitals, Supraoccipital, Petrosals.

b. Lateral loops (*'Anses latérales,'* V.). Alisphenoids, Orbitosphenoids.

c. Facial plate (*'Plaque faciale,'* V.). Entosphenoid (l'ethmoïde crânien, Ag.).

B. PROTECTIVE PLATES (*'PLAQUES PROTECTRICES,'* V.).

a. Superior plates. Parietals, Frontals, Nasals.

b. Lateral plates. Prefrontals, Postfrontals, Mastoids (temporaux, Ag.).

c. Inferior plates (*'Plaque buccale,'* V.). Basi- pre- sphenoid, Vomer.

FACIAL BONES. (OS DE LA FACE.)

I. *Maxillary arch.* Suborbitals (jugaux, Ag.), Maxillary, Premaxillary.

II. *Palatine arch.* Palatines, Entopterygoids, Pterygoids (transverses, Ag.).

III. *Mandibular arch.* Pretympanics ('caisses,' Ag.), Mesotympanics ('tympano-malleaux,' Ag.), Hypotympanics ('os carrés,' Ag.), Mandible.

IV. *Hyoidean arch.* Epitympanics ('mastoïdiens,' Ag.), Preoperculars, Stylohyals, Epihyals, Ceratohyals, Basihyals ('l'os lingual,' Ag.).

V. VI. VII. VIII. *Branchial arches.* 'Composés chacun de deux ou trois pièces et reunis sous le gorge par le corps de l'hyoïde.'

IX. *Pharyngeal arch.* 'Composé d'une ou de plusieurs pièces,' &c.—*Op. cit.* t. i. pp. 124, 130.

M. Vogt. With regard to the series of nine arches into which the facial ones are distributed, it may be remarked that the independence of the maxil-ary from the palatine, which is more apparent than real in the osseous fishes, eases to be manifested in any degree in the plagiostomes and lepidosiren: hat the first and second arches are suspended by their crowns with their aunches projecting freely outwards, whilst the third and fourth arches are uspended, in the reverse position, viz. inverted, with the crowns or key-stones ownwards: the four next arches are rather complete cinctures, their sum-nits meeting and being loosely suspended to the basis cranii, or, in pla-iostomes and cyclostomes, to the under part of the vertebral column of the unk. Although professing to base his classification upon developmental haracters, M. Agassiz owns with regard to the posterior branches of the axillary arch, *e. g.* the suborbitals, "that they appear to be rather formed y the dermal system." And this is unquestionably true: whilst the pala-nes, which are the true piers of the arch, are developed from the blastema f the same visceral arch as the maxillaries and premaxillaries.

The error in regard to the special homology of the suborbital bones, deter-ined by M. Agassiz as the malars, and which is so clearly exposed by the ructure of the skull of the *Psittacidæ* (*ante*, p. 41), has misled him in re-pect to the natural and typical constitution of the maxillary arch.

The mistake in reference to the special homology of the epitympanic (28*a*), etermined by M. Agassiz as the 'mastoid,' has, in like manner, influenced m in dissociating it from the other dismemberments of the tympanic pedicle, d referring it to a different arch.

With regard to the hyoid and branchial arches, it will be observed that I. Agassiz makes no distinction between the systems of the neuro- and lanchno-skeleton. An arch constant and ossified in all vertebrates where e rest of the endoskeleton is ossified, and which, even admitting M. Agassiz' ecial homology of the preopercular as the styloid process of the temporal, ould still be suspended in the inverted position, like a true hæmal arch, is aced in the same category as the branchial girdles, which are often cartila-nous when the hyoid is osseous, in bony fishes; and which disappear, in the etamorphosis of the tadpole, with the evanescent respiratory viscera for e support of which they are exclusively developed.

The constitution of a distinct 9th facial arch for the posterior pair of bran-ial girdles, which retain their gills in lepidosiren, though modified in sub-rvience to mastication in most osseous fishes, appears to be giving undue portance to an artificial or adaptive character. Finally, the natural con-ctions of the scapulo-coracoid arch in osseous fishes are totally disregarded, d it is left out of the enumeration of the bones of the head.

The unbiassed anatomist may find an element for judging of the natural aracter of the cranio-vertebral system propounded in the present Report, contrasting the classification of the bones of the fish's skull to which it ds, with that proposed by M. Agassiz, and with nature*.

Having thus responded to the objections advanced by Cuvier and M. gassiz to the interpretations of the segmental constitution of the bones of head which were open to the criticism of those great authorities in atomy, I proceed briefly to explain the segmental constitution of the bones

* I am bound here to say that in the discussion of the subject of this Report with M. ssiz, which, amongst other advantages of the meetings of the British Association, I en-ed at Southampton, he admitted, with his characteristic frankness, that some points of classification of the bones of the head in fishes would require reconsideration. One of eminent physiologists who was present at the debate which followed the reading of the ort, has recorded the impression it produced upon him in a review of my 'Hunterian tures on Vertebrata' in 'The British and Foreign Medical Review,' No. xlvi. p. 490.

of the trunk of the human subject according to the archetypal vertebra with which the segments in the head have been illustrated.

The first seven segments of the trunk consist each of centrum (fig. 25, *c*) neurapophyses (*n*), neural spine (*s*), and rudimental pleurapophyses (*pl*), which coalesce, in each segment, into one bone, called 'cervical vertebra' in anthropotomy. If the hæmapophyses (52′) have the same relation to their centrum which those of the seventh dorsal vertebra, in the *Ciconia Argala*, more obviously bear to theirs,—that is, being attached below and disunited at their upper ends from their pleurapophyses, which are short, stunted and anchylosed to the centrum,—and if, as the apparent homologues of 52′ in fishes would indicate, the atlas be actually the centrum to which such detached and shifted hæmapophyses belong, then the first will be the sole segment of the cervical region of the trunk in which those elements are ossified.

In the seven vertebræ which succeed the cervicals the pleurapophyses (*pl*) are progressively elongated; they are shifted from their proper centrum to the interspace between it and the next segment above, or in advance, and retain their moveable joints. The hæmapophyses (*h*) are cartilaginous and articulate with the ends of the pleurapophyses and with the hæmal spines (*hs*), which are flattened, slightly expanded, and ultimately blended into one bone called 'sternum.' The hæmal spine of the first typical segment remains longest distinct; it receives, also, the extremities of the displaced hæmapophyses (52′) and has been called 'manubrium sterni.' The hæmal spine of the seventh segment commonly continues longer distinct, and is later in becoming ossified, whence it is called 'ensiform cartilage': it probably includes the rudiments of some succeeding hæmal spines. In the four succeeding segments the pleurapophyses become progressively shorter, and the hæmapophyses, still cartilaginous, are severally attached by their lower attenuated ends to the pair in advance, leaving the hæmal arch incomplete below. In the next vertebra (19th from the skull) the still shorter pleurapophyses resume the exclusive articulation with their proper centrum; and the correspondingly short and pointed hæmapophyses terminate freely.

Those pleurapophyses and hæmapophyses which directly articulate with hæmal spines (sternum) are called collectively 'true ribs' (costæ veræ), the proximal element being 'the bony part of the rib' (pars ossea costæ), the distal one the 'cartilage of the rib.' The rest of the hæmal arches which are incomplete through the absence of the hæmal spine, are called 'false ribs' (costæ spuriæ); and the last, which terminates freely in the origin of the diaphragm, is a 'floating rib.' The centrum, neurapophyses and neural spine of each segment with freely articulated pleurapophyses coalesce into one bone called 'dorsal vertebra' in anthropotomy: these vertebræ are twelve in number. Each of the five succeeding segments is represented by the same elements (centrum and neural arch) coalesced that constitute the so-called dorsal vertebræ: they are called 'lumbar vertebræ' (fig. 25, L.): they have no ossified pleurapophyses; and the hæmapophyses of these segments are represented only by the aponeurotic 'inscriptiones tendineæ musculi recti' (*h″*).

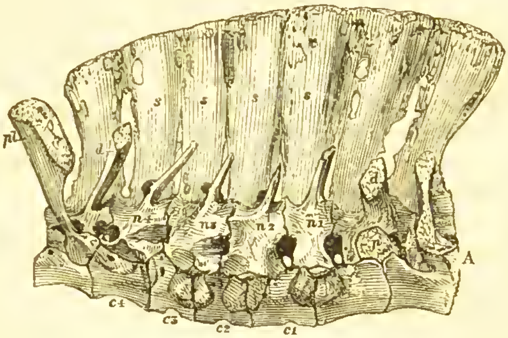
Certain elements of the five succeeding segments (*ib.* S.) coalescing together in the progress of growth form the bone called 'sacrum': and are described individually as sacral vertebræ. The first four of these each combine the same elements, coalesced, as in the neck; viz. centrum, neurapophyses, neural spine and short but thick pleurapophyses*: in the fifth sacral vertebra there are no

* J. Müller notices the rudimental ribs in the first and second sacral vertebræ of the human fœtus in his Anatomie der Myxinoiden, heft i. 1834, p. 240. Mr. Carlile has described (Report of British Association, 1837, p. 112), and Dr. Knox has figured (Lancet, 1839, p. 191) these ribs and their homotypes in the third and fourth sacral vertebræ.

osseous rudiments of pleurapophyses; and the neural spine is commonly un-leveloped. One or more typical segments are obviously completed by the neeting of the broad sides of the inverted arch (62, 63, 64) at the 'ischio-pubic symphysis' forming the 'pelvis' of anthropotomy. Before, however, ntering upon the difficult inquiry into the general homology of the pelvis, would beg to refer the reader to the analysis of the sacrum of the ostrich given at p. 95 : and I here subjoin a figure of seven of those vertebræ, rom an immature specimen, the pleurapophyses being removed from all ave the last (*pl*), in order to show the change of place of the neurapophyses 1–4, in relation to their centrums, *c* 1 to 4 : *d d* are the long diapophyses; the short parapophyses. The sacral spines, *s s*, are enormously developed.

In the bird the modification of the vertebral segments at the posterior egion of the trunk in relation o the transference of the whole veight of the body and fore-mbs (wings) upon the hind-mbs, is greater and more ex-ensive than in the 'bipes im-lume,' and the essential nature f the pelvic arch is still more nasked in the bird than in man. n order to obtain an insight nto the model according to hich it is constructed, we must escend still lower, even to the umblest of the vertebrated reatures that crawl upon the arth. The example which is here selected for that purpose is the perenni-anchiate amphibian called *Menopome Alleghanniensis.*

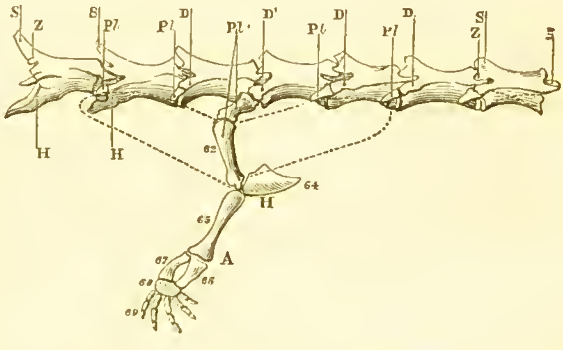
Fig. 27.



7 sacral vertebræ of a young ostrich (*Struthio camelus*).

The three anterior ver-bræ which answer in po-ion to the 'lumbar' in g. 25, differ chiefly in ha-ng rudimental pleurapo-yses (*Pl*) articulated to e ends of the diapophyses). In the next vertebra ediapophysis (*D′*) and the dimental pleurapophysis *l′*) are thickened and larged: a second pleur-ophysial rib-like piece (62) joined by one end to the eurapophysis, and by the ner to a broad partially ossified cartilage (64) which meets and joins its low, completing a hæmal arch and raising the vertebra in question to typical character. A radiated appendage, moreover, diverges on each e from the articulation between 62 and 64, and forms the hind-limb. Now special homology of this limb with the undivided filamentary appendage nilarly situated in the lepidosiren, and with the ventral fins of fishes, in descending series; and with the hind-limb of other reptiles, of birds and mammals in the ascending series, is unmistakeable, and, I believe, is gene-ly admitted: so that comparative anatomists have not hesitated to call rib-like bone, 62, 'ilium,' and the part, 64, 'pubis' in the menopome.

Fig. 28.



Sacral vertebra and appendage with contiguous vertebræ. Menopome.

The special homologies of these elements of the pelvis being thus determined, it follows, that their general homology, as it may be revealed by the simple condition of the pelvic arch in the species in which the pelvis, as complete and fixed to a sacrum, makes its first appearance in the animal kingdom, will be equally applicable to the parts under all their metamorphoses in the higher air-breathing vertebrates.

The correspondence of the segment of the endoskeleton in the menopome D′, Pl′, H, A, with the typical vertebra, as illustrated by fig. 15, is such, that any other explanation of its essential nature than as a representative or repetition of such fully developed segment or vertebra seems contrary to nature. The chief modification has its seat in the most peripheral part or appendage A. as compared with its simple homologue in the thoracic segment of the bird (fig. 15). If 62 and 64 are to be regarded as strangers to the vertebral system, new parts introduced for special purposes, and not as normal elements modified for such purposes, I am at a loss to know on what principles, or by what series of comparisons we can ever hope to attain to the higher generalizations of anatomy, or discover the pattern according to which the vertebrate forms have been constructed. It may be said that the arch which they constitute performs a new function, inasmuch as it sustains a locomotive limb which reacts upon the ground. But this new function arises in the menopome, rather out of the modifications of the appendage than of the arch itself. In so far as the mere support of the appendage is concerned, the inverted or hæmal arch Pl′, H, performs no new function, but one which is common to such arches in the thorax of birds, and to the less completely ossified homologous arches in the abdomen of fishes, where moreover the simple diverging appendages do give attachment to the muscles of locomotion. Comparing, then, the hæmal arch in question with that of the typical vertebra (fig. 15), we find that, like the scapulo-coracoid arch in fishes (fig. 5, H 1), its parts are open to two interpretations. The upper piece of *Pl′* may be the whole pleurapophysis, the lower, 62, the hæmapophysis, and the part, 64, the half of an expanded and bifid hæmal spine: or *Pl′* with 62, may be two portions of a teleologically compound pleurapophysis, and 64 the hæmapophysis, which would join with its fellow without, or with a mere rudiment of, a hæmal spine intervening. From the analogy of the scapulo-coracoid arch in fishes, which is proved by its modifications in higher animals to want the hæmal spine, it is most probable that such is the condition and true interpretation of the correspondingly simple pelvic arch under consideration. But the general relation of this arch to the hæmal one of the typical segment is not affected by the alternative.

I regard, therefore, *Pl′*, 62, as two portions of a fully developed pleurapophysis; and the pleurapophyses, *Pl*, *Pl* of the contiguous vertebræ as answering only to the upper portion of the pelvic one. In ascending from the menopome to the crocodile, we find the homologue of 62 broader than it is long and articulated to the thickened proximal portions of the pleurapophyses of two segments; and we observe, likewise, the pelvic arch completed below by two pairs of hæmapophyses: for the anterior pair the name of ‘ossa pubis’ is retained; to the posterior pair that of ‘ischia’ is given. In general homology these bones complete, as hæmapophyses, the two vertebral segments modified to form the sacrum of the crocodile; and the intermediate connecting piece (ilium) may be interpreted, as either the confluent distal portions of the pleurapophyses of both vertebræ, or as an expansion of one such portion, answering to 62 in the menopome, and intruding itself between the stunted pleurapophysis and distant hæmapophysis of the second sacral vertebræ in the crocodile.

In the bird the expansion of the element 62 proceeds to a further extent, and besides the proximal piece of the pleurapophysis of its own segment, the bone 62 is brought into connection with the homologous stunted or proximal nds of pleurapophyses of several contiguous segments, in the manner indi-ated by the dotted line in fig. 28, and in Pl. II. fig. 4, 62. Now, if the ilium, o expanded, were interpreted as the coalesced complementary portions of all he short pleurapophyses with which it articulates, its condition would be very imilar to that which Oken has attributed to the scapula. But its ossification adiates, as in the simple rib-like ilium of the menopome, from a common entre: there are no corresponding multiplications of hæmapophyses below; hese are restricted in the pelvis of all animals to the number which they resent in the crocodile. And since the scapula has been proved to be, under s most expanded form, the homologue of a single pleurapophysis, so also I m disposed to regard its homotype, the ilium, as maintaining under every ariety of form and proportion, the same fundamental singleness of character, s it presents on its first appearance in the perennibranchiate batrachian.

The first sacral vertebra, then, in man is complete; but its pleurapo-hysis is divided, and the lower portion expanded to form the so-called ilium' (62). The hæmapophysis (64) coalesces with that of the succeeding ertebra (63), and with its own pleurapophysis (62, fig. 25, and Pl. II. fig. 6).

The second sacral vertebra has its hæmapophysis (63, called 'ischium') ssified, but separated from its proper pleurapophysis by the expanded (iliac) ortion of that of the preceding vertebra, with which it coalesces, as well as ith the preceding hæmapophysis (pubis). The short and thick pleurapo-hyses of the third sacral vertebra also articulate in the adult with the ex-nded distal portions of those of the first sacral vertebra: but these (iliac ones) are restricted in infancy and early childhood to their connections ith the first and second sacral vertebræ, which connections are permanent most reptiles (Pl. II. fig. 3).

The fourth sacral vertebra consists, in man, of centrum, neurapophyses, d rudimental pleurapophyses; the fifth sacral vertebra of centrum and dimental neurapophyses, which rarely meet above the neural canal.

In each sacral vertebra the elements of the neural arch and rudimental s first coalesce together; and afterwards the vertebræ unite with each her and form the anthropotomical bone called 'sacrum.'

The first coccygeal vertebra in man consists of a centrum and of stunted urapophyses* wide apart above, but developing zygapophyses, which join ose of the last sacral vertebra, and diapophyses which extend outwards rther than those of the same vertebra. The neurapophyses are represented exogenous tubercles of bone in the second coccygeal vertebra; and the ird and fourth vertebræ are reduced to the centrums only.

The cartilaginous deposits in the primitive blastema of this extremity of trunk indicate a greater number of caudal vertebræ, and the rudimental l is proportionally longer in the embryo than in the adult. It is shortened, wever, by absorption prior to the commencement of ossification, and but r segments are indicated by depositions of the earthy salts in the situations oper to the above-specified elements of a typical vertebra: these finally alesce into a single bone "of a crooked pyramidal figure," which got its me of 'os coccygis' from its supposed resemblance to a cuckoo's beak †.

The early recognition of these and other specialities arising out of the va-us adaptive modifications of the typical segments of the human skeleton nd its expression, necessarily, in special terms, the convenience of which ll ensure their permanence; but the progress of anatomical science having

* "Shoulders of the os coccygis."—Monro, *l. c.* p. 142. † *Ib.* p. 141.

unfolded the primary form which is the basis of those modifications, there arises the same necessity for giving utterance to ideas of the generic character of the parts by general terms.

Inasmuch, however, as the different segments of the human skeleton deviate in various degrees from the common archetype, and as the different elements of such segments differ in their modifiability, anthropotomy has at no period wanted also its 'general terms' expressive of the recognised extent of such conformity: such terms also, indicating, obscurely indeed, so much perception of the pre-existing model as could be obtained from the study of one form, at a period when that form—the human frame—was viewed as something not only above, but distinct from, if not antithetica to the structures of the brute creation, and when it was little suspected that all the parts and organs of man had been sketched out, in anticipation so to speak, in the inferior animals. Thus the word 'vertebra' shows by the number of the segments or parts of segments to which it is applied in anthropotomy, a recognition of the degree in which the principle of repetition of similar parts more obviously prevails in the construction of th human endoskeleton. And, inasmuch as in some regions (the cervical, *e.g.* the 'vertebra' includes all the elements of the typical segment, there developed it has been retained in homological anatomy, but, with a more consistent an definite meaning, as the technical term of the primary segment of th endoskeleton in all vertebrate animals.

The 'true vertebræ' of anthropotomy are those segments which retain th power of moving upon each other; and the term is applied in a peculiar an empirical sense very different from the meaning which the anatomist at taches to a true or typical vertebra. The 'false vertebræ' of anthropotom are those segments or parts of segments forming the lower or hinder extrem of the endoskeleton, and which do not admit of reciprocal motion at the joints. And Monro, admitting that the condition of even the human c coccygis sometimes militates against the definition, meets the objection b arguing for the speciality of that bone, and with as good or better reaso than those who have subsequently contended against admitting the crani segments into the category of vertebræ. "From the description of this bone (os coccygis), "we see how little it resembles *vertebræ*; since it seldom ha processes, never has any cavity for the spinal marrow, nor holes for the pa sage of nerves*."

Embryology has since demonstrated that the parts of the os coccygis a originally in vertebral relation with the neural axis; and that this is subs quently withdrawn by a concentrative movement, which in like mann withdraws it from the terminal segment at the opposite extreme of the end skeleton. The homology of the divisions of the sacrum with the true ve tebræ is admitted by Monro, because of the perforations for the nerves: an this character is still retained in the nasal vertebra in the form of the crib form foramina, although its neurapophyses, like those of the sacrum, ha lost their primitive relation to the neural axis.

Homological anatomy, therefore, teaches, that the term 'vertebra' shou not only be applied to the segments of the human skeleton in the techni and definite sense illustrated by figs. 14 and 15, but be extended to the modified and reciprocally immoveable segments which terminate the enc skeleton superiorly, and are called collectively 'skull.' (Pl. II. figs. 1 to 6, C

The term 'head,' then, indicates a region of specially modified vertebræ, li the terms 'neck,' 'chest,' 'loins,' &c.; and amongst the species of the prim segments characterized by specific modifications, the 'cranial' vertebræ m

* Monro, *l. c.* p. 143.

be added to the 'cervical,' 'thoracic or dorsal,' 'lumbar,' 'sacral,' and 'coccygeal or caudal.'

Such, with reference to the 'general' term 'vertebra,' seems to be the advance of which anthropotomical science is susceptible, in order to keep progress and be in harmony with anatomy.

As to the elements of the typical vertebra, anthropotomy has also its general phrases (see Table II. column vi. 'Soemmerring.'), some of which are equivalent to the clearly defined technical terms of such elements in anatomy properly so called.

The serial homology of the centrum (*corpus vertebræ*) has been recognised in all the so-called 'true vertebræ,' and in some of the 'false vertebræ:' thus Monro says, "The fore-part of the *os sacrum*, analogous to the bodies of the true vertebræ, is smooth and flat*." But their smooth and flat homotypes in the skull have only the special names of 'basilar' and 'cuneiform' processes; of 'processus azygos' and 'vomer.' The 'neurapophyses' are recognised as repetitions of the same part under the definitions of 'a bony bridge produced backwards from each side of the body of the vertebra,' of '*arcus posterior vertebræ*,' of 'vertebral laminæ' or 'pedicles.' Monro describes these rudimental elements in the last sacral vertebra as 'knobs,' and in the first coccygeal vertebra as its 'shoulders.' In the skull they receive the special definitions of "the pieces of the occipital bone situated on each side of the great foramen; from which nearly the whole condyles are produced†" (*partes laterales seu condyloideæ*, Soem.); 'great' or 'temporal wings of the sphenoidal bone ‡;' 'orbitar wings' or 'processes of the sphenoidal bone;' 'nasal' or vertical plate' and 'crista galli' of the ethmoid ('*pars media ossis æthmoidei*,' Soem.).

The neural spines are called generally '*spinal processes*' in every segment of the trunk: in the head they are known only by the special names of 'occipital plate,' 'parietal bones,' 'frontal bone,' 'nasal bones.'

The pleurapophyses, when free, long, and slender, are called '*ribs*,' 'vertebral ribs,' or 'bony parts of the ribs'; when short and anchylosed, they are called, in the neck, "the second transverse processes that come out from the sides of the body of each vertebra §;" (*radix prior processus transversi vertebræ*, Soem.;) in the sacrum 'transverse processes' and 'ilium'; in the skull, scapula', 'styloid process of the temporal bone,' 'external auditory or tympanic process of the same bone'; 'palatine bone.'

In like manner the serial homology of the hæmapophyses is recognised in the thoracic region by the general term 'cartilages of the ribs' or 'cartilages of the sternum' ‖ there applied to the same elements of twelve successive segments. When ossified in other vertebræ they have received the special names of 'ischium,' 'pubis,' 'coracoid process of the scapula,' 'clavicle,' 'appendix or lesser cornua of the hyoid bone,' ('*crura superiora*,' '*os linguale superius*,' Soem.), 'lower jaw' or *mandibula*, 'upper jaw' or *maxilla*.

The exigences of descriptive anthropotomy and its highly important applications to Medicine and Surgery necessitate such special nomenclature, and the reform which that nomenclature chiefly requires is the substitution of names in the place of phrases for the parts of the human body.

* Monro, *l. c.* p. 138. † *L. c.* p. 76. ‡ *L. c.* p. 86. § *L. c.* p. 126.

‖ Laurentius, in describing the human thoracic pleurapophyses, says, "Earum duplex articulatio, altera cum spondylis dorsi, altera cum sterni cartilaginibus" (Anatomica Humani Corporis, Fol. 1600, p. 94). The perception of the essential distinctness of the vertebral ribs had not then been blunted by the constant repetition of the conventional idea of their forming an ossified part of a whole, completed by the hæmapophysis under the name of the 'cartilago costæ.' In birds it is not uncommon to find the hæmapophyses not only ossified, but some of them attached to the sternum, and detached from the pleurapophyses.

But the retention and use of specific names for specially modified elements in the different segments by no means preclude the entertainment of general ideas and the necessity of expressing them by generic names for the homologous elements in the entire series of vertebræ.

If anthropotomy is to make corresponding progress with anatomy, and to derive the same light from the generalizations of zootomical science which medical botany has done from general botanical science, its nomenclature must expand to receive those generic terms which express the essential nature of the parts, heretofore named and known only according to the results of particular and insulated observation. A term which truly expresses the general homology of a part enunciates the most important and constant characters of such part throughout the whole animal series, and implies therefore a knowledge of such characters in that part of the human body, when used and understood by the human anatomist. Before the cuneiform process of the occipital bone could be defined as the 'occipital centrum,' the modifications and relations of the homologous part in all classes of vertebrate animals had to be accurately determined. The generic homological term expresses the sum or result of such comparisons, and the use of such terms by the anthropotomist implies his knowledge of the plan or pattern of the human frame which lies at the bottom of all the modifications that raise it to an eminence so far above those of all other vertebrate animals.

In no species, however, is each individual segment of the endoskeleton so plainly impressed with its own individual characters, as in Man; the praetised anthropotomist, for example, will at once select and name any given vertebra from either the cervical, the dorsal, or the lumbar series. During that brilliant period of human anatomy which was illuminated by a Fabricius, an Eustachius, a Fallopius, and a Laurentius, the terms expressive of the recognition of such specific characters were more numerous and often more precise than in our modern compilations. Pleurapophyses were individualized in the thorax as well as in the head: the 'antistrophoi,' 'stereai' and 'sternitides,' for example, were distinguished from the other 'pleurai gnesiai'*.

General anatomical science reveals the unity which pervades the diversity, and demonstrates the whole skeleton of man to be the harmonized sum of a series of essentially similar segments, although each segment differs from the other, and all vary from their archetype.

Chapter III.—Serial Homology.

Since, then, we are led by the observations, comparisons and reasonings recorded in the preceding parts of this Work, to recognise, as the fundamental type of the vertebrate endoskeleton, a series of segments repeating each other in their essential characters, it follows that, not only the power of determining the homologous bones throughout the vertebrate series, but also throughout the vertebral segments of the same individual, is included in such generalization.

The recognition of the same elements throughout the series of segments of the same skeleton I call 'the determination of serial homologies.' This kind of study appears to have been commenced by the gifted Vieq d'Azyr in his 'Mémoire' entitled "Parallèle des os qui composent les extrémités," and printed in the Mémoires de l'Académie des Sciences for the year 1774, and

* Anatomica Humani Corporis, &c., multis controversiis et observationibus novis illustrat: Andr. Laurentio, fol. 1600, p. 95.

Condorcet, in his Report on this ingenious Essay, speaks of it as "un essai d'une autre espèce d'Anatomie comparée, qui jusqu'ici a été peu cultivée."

Vicq d'Azyr compares, or points out the serial homology of, the scapula with the ilium, the humerus with the femur, the two bones of the fore-arm with the two bones of the leg, the small bones of the carpus with those of the tarsus, the metacarpus with the metatarsus, and the fingers with the toes. He is not so happy in his particular as in his general determinations: his choice in the leg, for example, of the homotypes of the radius and ulna in the fore-arm, is erroneous; but the whole memoir is an admirable example of the appreciation of correspondences which later researches in the same direction have proved to flow from a higher and more general law of uniformity of type. It is, indeed, a striking instance of the secret but all-prevailing harmony of the vertebrate structure that serial homologies should be determinable to such an extent in the parts of the diverging appendages, which are the seat of the greatest amount and variety of deviations from the fundamental type.

It will, of course, be obvious that the humerus is not 'the same bone' as the femur of the same individual in the same sense in which the humerus of one individual or species is said to be 'the same bone' as the humerus of another individual or species. In the instance of serial homology above-cited, the femur, though repeating in its segment the humerus in the more advanced segment, is not its namesake, not properly, therefore, its 'homologue'. I propose, therefore, to call the bones so related serially in the same skeleton 'homotypes,' and to restrict the term 'homologue' to the corresponding bones in different species, which bones bear, or ought to bear, the same names.

In the skull those bones are homotypes, or repetitions of the same essential part in the series of vertebral segments, which succeed each other lengthwise, as in the last four columns of the subjoined Table:—

Vertebræ.	Occipital.	Parietal.	Frontal.	Nasal.
Centrums	Basioccipital	Basisphenoid	Presphenoid	Vomer.
Neurapophyses	Exoccipital	Alisphenoid	Orbitosphenoid	Prefrontal.
Nasal spines	Supraoccipital	Parietal	Frontal	Nasal.
Parapophyses	Paroccipital	Mastoid	Postfrontal	None.
Pleurapophyses	Scapula	Stylohyal	Tympanic	Palatal.
Hæmapophyses	Coracoid	Ceratohyal	Articular	Maxillary.
Hæmal spines	Episternum	Basihyal	Dentary	Premaxillary.
Diverging appendages	Fore-limb or fin	Branchiostegals	Operculum	Pterygoid and Zygoma.

Thus the basioccipital, basisphenoid, presphenoid and vomer are homotypes with the centrums of all the succeeding vertebræ. The exoccipitals, alisphenoids, orbitosphenoids, and prefrontals, are homotypes with the neurapophyses of all the succeeding vertebræ. The paroccipitals, mastoids and postfrontals are homotypes with the transverse processes of all the succeeding vertebræ. The supraoccipital, parietal, frontal and nasal are homotypes with the vertebral neural spines.

The petrosals, sclerotals, and turbinals are homotypes of each other, as being respectively sense-capsules of the splanchno-skeleton.

The suprascapula and scapula are together the homotypes of the stylohyal and epihyal; of the tympanic, whether single or divided; and of the palatal: and all these are the homotypes of the pleurapophyses collectively, whether modified as ribs, hatchet-bones, or iliac bones, in the rest of the vertebral segments.

The coracoid is the homotype of the ceratohyal, this of the articular division of the mandible (with its subdivisions called angular, sur-angular and coronoid, in cold-blooded animals), and this, again, of the maxillary bone: all four being homotypes of the hæmapophyses of the remaining vertebral segments, whether modified to form clavicles, pubic bones or ischia, chevron-bones, sternal ribs, abdominal ribs, cartilages of ribs, abdominal cartilages or tendinous intersections of the modified intercostal muscles called 'recti abdominis.'

The entosternal, when present, is the homotype of the basihyal, of the dentary or premandibular, and of the premaxillary bones; and these collectively are homotypes of the hæmal spines of the rest of the vertebral segments, whether retaining their spinal shape as in the caudal hæmapophyses, or flattened as ordinary 'sternal bones,' or expanded and subdivided, like the neural spines in the cranium, in order to complete below the thorax of the bird or to form the plastron of the turtle*.

There reigns a beautiful parallelism in the kind and degree of modification of the parts of the neural with the corresponding parts of the hæmal arch of the same vertebral segment: and as the serial homologies which have just been enunciated succeed each other longitudinally (horizontally in beasts, vertically in man) in the axis of the vertebral column, so these manifest themselves in a direction perpendicular to that axis.

The manubrium sterni of the bat developes a spine downwards, as the supraoccipital of the fish sends a spine upwards: the expanded manubrium sterni of the whale repeats the condition of the supraoccipital in birds and mammals. The form of the ordinary sternal bones in mammals is repeated by the parietal and supraoccipital bones of the crocodile. The divided sternum of the young ostrich, before the two lateral ossifications have coalesced at the median suture, repeats the condition of the divided parietal in most mammals. The development of the crista from the obliterated suture of the lateral halves of the expanded hæmal spine in the thorax of birds is paralleled by the development of the crista from the obliterated suture of the expanded neural spine in the cranium of carnivores. The interposition of the entosternal piece in the chelonian carapace parallels below the interposition of the interparietal bone in the rodent cranium above.

Thus modifications and developments of the same kind and degree manifest themselves in the upper (neural) as in the lower (hæmal) peripheral elements of the vertebræ; and though not always in the same vertebra, nor in the same animal, yet they are sufficiently exemplified in the myelencephalous series generally, to establish the conclusion that the hæmal spines under all their modifications are vertical homotypes, not of the centrums, as Oken, Meckel and De Blainville have supposed, but of the neural spines of the same vertebræ. In the composition of the neural arch of the occipital, parietal and frontal vertebræ, we find the neurapophyses repeating the pleurapophyses of the hæmal arch, and the parapophyses repeating the hæmapophyses in their relative positions to the centrum and the spine or key-bone of such arches.

Symmetry, polarity, or serial homology of parts of the same vertebral segment is usually still more strictly preserved in the transverse direction, and is so obvious, as to have immediately led to the detection of the homologous parts, which are accordingly distinguished as 'right' and 'left.'

Returning to the consideration of those serial homologies with which Vicq d'Azyr commenced the study of these relations, I may remark that the bones of the fore- and hind-limbs of some of the marsupial quadrupeds best illustrate the true relations which my revered Preceptor in Anatomy, Dr. Barclay†,

* These homotypical relations will be readily traced by the markings characteristic of the vertebral elements in Plate II.

† In his explanations of Mitchel's Plates of the Bones, 4to, 1824, pl. 24, figs. 3 and 4, Dr. Barclay, without referring to Vicq d'Azyr's Memoir, simply enunciates the correct view of the serial homology of the bones of the fore-arm and leg, as follows:—"On com-

was, I believe, the first to enunciate in respect of the bones of the fore-arm and leg.

The skeleton of the *Phalangista* or *Phascolomys* plainly demonstrates that the tibia (Pl. II. fig. 16, 66) is the homotype of the radius (*ib.* fig. 15, 55 , and that the fibula (*ib.* fig. 16, 67) is the homotype of the ulna (*ib.* fig. 15, 54). In the wombat the part of the fibula (67′) representing the olecranon (*o*) is a detached sesamoid, as the olecranon itself is in the penguin and the bat: in the ornithorhynchus the fibula assumes those proportions and developes that process from its proximal end, the want of which in man and most mammals deceived Vicq d'Azyr, as it has misled, more recently, M. Cruvelhier. The complex explanation of the serial homologies of the bones of the upper and lower extremities proposed by the last named pains-taking anthropotomist*, involves more unnatural transpositions and combinations of the parts than those of the D'Azyrian hypothesis, which its ingenious author could not but admit seemed paradoxical; viz. that the anterior member of one side of the body repeated or corresponded with the posterior member of the opposite side. Cuvier, however, seems to sanction this idea by repeating the statement of Vicq d'Azyr, "C'est la droite d'une paire, qu'il faut comparer à la gauche de l'autre†."

M. Flourens has exposed in detail the fallacies of this view in an excellent memoir in the 'Annales des Sciences' for 1838 (t. x. p. 35); in which he arrives at the same conclusions as Dr. Barclay, and from similar considerations from Comparative Anatomy, as to the serial homologies of the bones of the fore-arm and leg; and he confirms those of the carpal and tarsal bones, which had been so truly and acutely discerned by Vicq d'Azyr.

In mammalian quadrupeds generally the fore-limb takes the greater share in the support, the hind-limb in the propulsion of the body. The *manus* is accordingly commonly shorter and broader than the *pes*; this may be seen in the terminal segment of even the monodactyle hand and foot of the horse. Consequently the transverse direction prevails in the arrangement of the carpal bones and the longitudinal in that of the tarsal bones. The difference is least in the carpus and tarsus of the long and slender fore- and hind-hands of the quadrumana. If the carpus of the chimpanzee, for example, be compared with that of man, the first difference which presents itself is the comparatively small proportion of the scaphoid which articulates with the radius, as compared with that in man, in whom the distal articulation of the radius is equally divided between the scaphoides and lunare which are on the same parallel transverse series. In the orang (Pl. II. fig. 13), the divided scaphoid (*s*, *s′*) extends, almost as much from the os lunare as from the radius, along the radial side of the carpus, to reach the trapezium (*t*) and trapezoides (*z*); it is in great part interposed between the lunare (*l*) of the proximal row and the trapezium and trapezoid of the distal row of the carpal bones. The similarity of its connections, therefore, in the carpus with those of the scaphoid in the tarsus (Pl. II. fig. 14, *s*) is so close that the serial homology of the two bones is unmistakeable. The

aring the atlantal (pectoral) and sacral (pelvic) extremities, the fibula is found to be the bone orresponding to the ulna; and accordingly, upon extending our researches to Comparative natomy, we perceive it exhibiting the like variety and unsteadiness of character, sometimes rge, sometimes small, and sometimes merely a process of the tibia," &c. He does not push s comparison to the bones of the distal segment of the limbs.

* "L'extrémité supérieure du tibia est représentée par la moitié supérieure du cubitus, la moitié inférieure du tibia par la moitié inférieure du radius; tandis que le péroné est présenté par la moitié supérieure du radius et par la moitié inférieure du cubitus."—*Anatoie Descriptive*, t. i. p. 315.

† Leçons d'Anat. Comp. t. i. 1836, p. 312.

astragalus (*ib. a*), then, in the foot, repeats the os lunare (*l*) in the hand, but usurps the whole of the articular surface of the tibia, and presents a larger proportional size, especially in man, whose erect position required such exaggerated development of the astragalus, or homotype of the lunare. The prominent part of the calcaneum (Pl. II. figs. 6 and 24, *cl'*) obviously repeats the prominent pisiforme (fig. 6 and 13, *p*), and the body of the calcaneum (fig. 6 and 14, *cl*) articulates with the fibula, as the cuneiforme (fig. 6 and 13, *cu*) articulates with the ulna. The strain upon the homotype of the pisiforme (*cl'*) to produce the required effect in raising the back-part of the foot with its superincumbent weight upon the resisting ends of the toes, required its firm coalescence with the homotype of the cuneiforme; in other words, the cuneiforme and pisiforme of the carpus represent together the os calcis of the tarsus. With regard to the other bones there is no difficulty; the cuboid (fig. 14, *b*) supports the two ulnar digits, *iv*, *v*, of the foot, as the unciform bone (*u*) does those, IV, V, of the hand: the ecto-cuneiform (fig. 14, *ce*) supports the digitus medius, *iii*, of the foot as the os magnum (*m*) does that of the hand: the meso-cuneiform (fig. 14, *cm*) supporting the toe, *ii*, is the homotype of the trapezoid supporting the finger, II, and the ento-cuneiform (fig. 14, *ci*) is the homotype of the trapezium (fig. 13, *t*).

It is no unusual exception that of two essentially distinct bones in one segment being represented by their coalesced homotypes—a single bone—in another segment, as in the explanation above given of the serial homology of the calcaneum. The scaphoides and astragalus in the tarsus of the cat and wombat (fig. 16, *sc*, *a*) are represented by the single scapho-lunar bone in the carpus (fig. 15, *sc*, *l*). The scaphoid and a cuneiform bone in the tarsus of the sloth and megatherium are represented by the single scapho-trapezium in the carpus. The scaphoid and unciform bones in the carpus of the ox are represented by the single 'scapho-cuboid' bone in the tarsus (fig. 18, *s*, *b*).

I have long entertained the opinion that an appreciation, vague and indistinct, perhaps, of certain serial homologies, may have been associated with, if it did not suggest, the epithets "scapula of the head," "femur of the head," &c. applied to certain cranial bones by Oken and Spix.

To Cuvier this language seemed little better than unintelligible and mystical jargon, and he alludes to it with ill-disguised contempt*. It has been commonly cited by those who have followed the great palæontologist in depreciating the cranio-vertebral theory, as a sufficient instance, needing no comment, of the extravagances essentially inherent in such attempts to recognise and explain the fundamental pattern to which the modifications of the cranial bones are subordinated. And it must be confessed that the expressions by which the philosophical anatomists of the school of Schelling have endeavoured to illustrate in the animal structures the transcendental idea of 'the repetition of the whole in every part,' have operated most disadvantageously and discouragingly to the progress of calm and dispassionate inductive inquiry into that higher law or condition upon which the power of determining the special homologies of the bones of the skeleton depends. Nevertheless the utterances of gifted spirits to whom the common intellectual storehouse is indebted for such original and suggestive generalizations as those contained in the "Program über die Bedeutung der Schädelknochen" are

* "Quant à M. Oken—il déclare les pièces en question les parties écailleuses des temporaux, ou, selon son langage mystique, '*la fourchette du membre supérieur de la tête.*'"—Ossem. Foss. v. pt. ii. p. 75.—"Cet *humérus de la tête* de M. Oken devient pour M. Spix le *pubis* de cette même tête; ou, pour parler un langage intelligible, un des osselets de l'ouïe, savoir, le marteau."—"M. Spix croit aussi qu'il répond à la partie écailleuse du temporal, qu'il décore du titre d'*iléon de la tête.*"—&c. *Ib.* pp. 85, 86.

entitled to respectful consideration, even when they happen to be least intelligible or most counter to the conventional expressions of the current anatomical knowledge of the day; and, for my own part, I must acknowledge that reiterated attempts to detect their latent meaning have not been wholly unproductive.

With regard, for example, to the term 'scapula capitis' applied by Oken to the tympanic bone in birds (fig. 23 and Pl. II. fig. 4, 28), it is quite possible that some appreciation of its serial homology with ribs and other modifications of the pleurapophysial element, besides that exhibited by the blade-bone, may have lain at the bottom of the expression. And, we may ask, whether the error here be not rather in the mode of stating the relationship than in the relationship itself? Had Oken, for example, said that the tympanic bone of the bird was a modified 'pleurapophysis,' or expressed by any other equivalent general term his idea of its standing in such general relation to its proper cranio-vertebral segment, his language would not only have been accurate, but might have been intelligible to Cuvier. When Oken called the 'tympanic' a 'cranial scapula' he unduly extended the meaning of the term 'scapula,' and converted it from a specific to a generic one. The tympanic is the homotype of the scapula, both being modified pleurapophyses, but each has an equal claim to its proper or specific name indicative of their respective modifications.

I am aware that Oken meant more than mere serial homology when he called the tympanic the 'blade-bone of the head': it is part of the phraseology of the hypothesis of the head being a repetition of the whole body, &c. But at the time when that anatomist wrote it was not known or suspected that the head already possessed the scapula, and that the modified pleurapophysis so called, actually appertained to a segment of the skull (fig. 5, p. 17, and Pl. II. figs. 2 and 7, 50, 51). In the terms '*femur capitis*,' '*tibia capitis*,' '*fibula capitis*,' '*pes capitis*,' applied by Oken to the parts of the teleologically compound mandibular ramus, and in those of '*ulna capitis*' and '*manus capitis*,' applied to the distal segments (21, 22) of the maxillary arch, we have not only instances of the attempt to express general relations of repetition or homology by special terms, but these modes of expressing the serial homologies of nos. 29, 30, 32, and of 21 and 22, betrays the misappreciation of the general homologies of the locomotive extremities, and their relations to the vertebral arches supporting them.

To gain an insight into whatever proportion of truth may be involved in the ideas signified by the phrases above cited, it is necessary to determine the essential nature of the parts called 'femur,' 'tibia,' 'humerus,' 'ulna,' 'manus,' 'pes,' &c., or the general homology, in short, of locomotive members, and the attempt to master this problem has been not the least difficult part of the present inquiry. Cuvier has offered no opinion, nor does he appear to have ever troubled himself with the attempt to decipher the signification of the locomotive members of the vertebrate animals; *i. e.* of what parts of the common vertebrate model they are the modifications.

Oken's idea of the essential nature of the arms and legs is, that they are no other than 'liberated ribs': "Freye Bewegungsorgane können nichts anderes als frey gewordene Rippen seyn *."

Carus, in his ingenious endeavours to gain a view of the primary homologies of the locomotive members, sees in their several joints repetitions of vertebral bodies (*tertiar-wirbel*)—vertebræ of the third degree†—a result of an ultimate analysis of a skeleton pushed to the extent of the term 'vertebra' being made to signify little more than what an ordinary anatomist would call a 'bone.'

* Lehrbuch der Natur Philosophie, p. 330, 8vo, 1843.

† Urtheilen des Knochen und Schalengerüstes, fol. 1828.

But these transcendental analyses sublime all differences, and definite knowledge of a part evaporates in such unwarrantable extension of the meaning of terms.

It has been, however, I trust, satisfactorily demonstrated that a vertebra is a natural group of bones, that it may be recognised as a primary division or segment of the endoskeleton, and that the parts of that group are definable and recognizable under all their teleological modifications, their essential relations and characters appearing through every adaptive mask.

According to the definition of which a vertebra has seemed to me to be susceptible, we recognise the centrum, the neural arch, the hæmal arch, and the appendages diverging or radiating from the hæmal arch. The centrum, though the basis, is not less a part of a vertebra than are the neurapophyses, hæmapophyses, pleurapophyses, &c.; and each of these parts is a different part from the other: to call all these parts 'vertebræ' is in effect to deny their differential and subordinate characters, and to voluntarily abdicate the power of appreciating and expressing them. The terms 'secondary' or 'tertiary vertebræ' cannot, therefore, be correctly applied to the parts or appendages of that natural segment of the endoskeleton to the whole of which segment the term 'vertebra' ought to be restricted.

So likewise the term 'rib' may be given to each moiety of the hæmal arch of a vertebra; although I would confine it to the pleurapophyses when they present that long and slender form characteristic of the thoracic abdominal region, viz. that part of such modified hæmal or costal arch to which the term 'vertebral rib' is applied in comparative anatomy and the term 'pars ossea costæ' in anthropotomy: but, admitting the wider application of the term 'rib' to the whole hæmal arch under every modification, yet the bony diverging and backward projecting appendage of such rib or arch is something different from the part supporting it.

Arms and legs, therefore, are developments of costal appendages*, but are not ribs themselves liberated: although liberated ribs may perform analogous functions, as in the serpents and the *Draco volans*.

If then the arms or pectoral members be modified developments of the diverging appendage of the scapulo-coracoid arch †, and if this be the hæmal arch of the occipital vertebra, it follows that the pectoral members are parts of the head, and that the scapula, coracoid, humerus, radius and ulna, carpals, metacarpals and phalanges, are essentially bones of the skull.

The transcendentalism, therefore, which requires for its illustration that the maxillary arches be the arms and hands of the head, meets its most direct refutation in the fact of the diverging appendages, properly called arms and hands, belonging actually to one of the modified segments of which the head itself consists.

The head is, therefore, in no sense a summary or repetition of all the rest of the body: the skull is a province of the whole skeleton, consisting of a series of segments or 'vertebræ' essentially similar to those of which the rest of the skeleton is constituted.

Most of the phrases by which Spix ‡ attempted to systematize and carry out the repetition-hypotheses of Schelling and Oken, as applied to the osteology of the vertebrate skull, may be similarly explained, and when well-winnowed some grains of truth may be recovered.

In denominating the palatine bone the 'hyoid bone of the face,' Spix endeavours to express a relation of general homology by a term which should be confined to the enunciation of a special homology: but he adds "cornui ossis hyoidei anteriori analogum," which shows an almost correct appreci-

* Pl. II. fig. 1, *a a*. † Ib. fig. 7, *a a*. ‡ Cephalogenesis, fol. 1815.

ation of the serial homology of the palatine bone. It answers, however (see no. 20 in figs. 1–6, Pl. II.), in the maxillary arch to the stylo-hyal or proximal element (no. 38) of the hyoidean arch, not to the cerato-hyal or hæmapophysial element (40); and it needs only to recognise the palatine as the 'pleurapophysis' of its vertebral segment, to appreciate all its true serial homologies. It might as well have been called the 'tympanic pedicle of the face,' the 'styloid process of the face,' the 'scapula of the face,' or the 'ilium of the face', according to Oken's and Spix's faulty method of expressing serial homological relations, since it holds in its vertebral segment the same place which each of the above-named bones respectively does in its segment.

So also, with regard to the term 'os facici iliacum' applied by Spix to the mastoid (s), the error lies not only in the application of a special term to express a general homological relation, but in the supposed serial homology so expressed. Had Spix detected, in a cranial vertebra, the precise element answering to that called 'iliac bone' in a post-abdominal vertebra, yet it would have been more proper to have signified such serial homology by giving the general term applicable to such parts, as abstract vertebral elements.

The fact is, however, that the mastoid (s) is the parapophysis of its vertebra, whilst the ilium is a portion of the pleurapophysis of its vertebra; and the mastoid is serially homologous with the transverse process of a sacral vertebra (fig. 27, *p*), not with its expanded rib or 'ilium'; it is not, therefore, a repetition of the ilium in the skull. The true expression of the ideas which suggested the terms 'ilium of the head,' 'scapula of the head,' &c., will be found in the true enunciation of the serial homologies of the vertebrate skeleton.

Conclusion.

It finally remains for future inquiry, admitting the explanation of the endoskeletal archetype given in the present Essay to be the true one, whether such is the ultimate attainable generalization, or whether we may not gain an insight into the nature of the force by which all the modifications of the vertebrate skeleton, even those subservient to the majesty of man himself, are still subordinated to a common type.

We perceive in the fact of the endoskeleton consisting of a succession of segments similarly composed,—in the very power, in short, of enunciating special, general and serial homologies,—an illustration of that law of vegetative or irrelative repetition which is so much more conspicuously manifested by the segments of the exoskeleton of the invertebrata; as, for example, in the rings of the centipede and worm, and in the more multiplied parts of the skeletons of the echinoderms.

The repetition of similar segments in a vertebral column, and of similar elements in a vertebral segment, is analogous to the repetition of similar crystals as the result of polarizing force in the growth of an inorganic body.

Not only does the principle of vegetative repetition prevail more and more as we descend in the scale of animal life, but the forms of the repeated parts of the skeleton approach more and more to geometrical figures; as we see, for example, in the external skeletons of the echini and star-fishes: nay, the calcifying salt actually assumes in such low-organized skeletons the very crystalline figures which characterize it when deposited, and subject to the general polarizing force, out of the organized body. Here, therefore, we have direct proof of the concurrence of such general and all-pervading polarizing force with the adaptive or special organizing force in the development of an animal body.

The marvellous phænomena of this development have, hitherto, been explained by two hypotheses or forms of expression—the one, as the result of 'vital properties' either peculiar to living matter or common to all, but latent in dead, matter; the other, as due to the operation of one or more 'vital principles,' vital forces, dynamics or faculties, answering to the ἰδέαι of Plato, deemed by that philosopher to be superadded to matter and mind, and which he defined as a sort of models, or moulds in which matter is cast, and which regularly produce the same number and diversity of species.

Now besides the ἰδέα, organizing principle, vital property, or force, which produces the diversity of form belonging to living bodies of the same materials, which diversity cannot be explained by any known properties of matter, there appears also to be in counter-operation during the building up of such bodies the polarizing force pervading all space, and to the operation of which force, or mode of force, the similarity of forms, the repetition of parts, the signs of the unity of organization may be mainly ascribed.

The platonic ἰδέα or specific organizing principle or force would seem to be in antagonism with the general polarizing force, and to subdue and mould it in subserviency to the exigences of the resulting specific form.

The extent to which the operation of the polarizing or vegetative-repetition-force is so subdued in the organization of a specific animal form becomes the index of the grade of such species, and is directly as its ascent in the scale of being. The lineaments of the common archetype are obscured in the same degree: but even in Man, where the specific organizing force has exerted its highest power in controlling the tendency to type and in modifying each part in adaptive subserviency to, or combination of power with, another part, the extent to which the vegetative repetition of segments and the archetypal features are traceable indicates the degree in which the general polarizing force may have operated in the arrangement of the parts of the developing frame: and it is not without interest or devoid of significance that such evidence should be mainly manifested in the system of organs in whose tissue the inorganic earthy salts most predominate.

With regard to the 'adaptive force,' whatever may be the expressions by which its nature and relations, when better understood, may be attempted to be explained, its effects must ever impress the rightly constituted mind with the conviction, that in every species "ends are obtained and the interests of the animal promoted, in a way that indicates superior design, intelligence and foresight; but a design, intelligence and foresight in which the judgement and reflection of the animal never were concerned; and which, therefore, with Virgil, and with other studious observers of nature, we must ascribe to the Sovereign of the universe, in whom we live, and move, and have our being*."

* See Barclay, Life and Organization, 8vo, 1822.

Y.	SOEMMERRING[39].	
	Names.	*Nos.*
[13]; sous-oc	ior sive basilaris partis occipitalis ossis	1.
férieur (in	ueno-occipitalis.	
[9] and ex-o	eralis sive condyloidea, &c.	2.
	ccipitalis stricte sic dicta, &c.	3.
....	[9]	51.
es, birds ar	us coracoideus [9]	52.
)[24 & 9]	la [9]	52′.
[24 & 9]	ieri [9]	53.
birds and		
birds and	....	54.
u carpe (in	....	55.
	rpi et metacarpi [9]	56.
du métac	ges digitorum [9]	57.
....		
....	....	58.
....	....	71.
....	....	72.
	....	73′.
....		
....	male	73.
	....	74.

been appl *Ibid.* p. 516): but he also ascribes a distinct petrosal in birds, teil der Schläfbein) to chelonians, ophidians and sau- *id.* p. 507), which must be either part of the exoccipi- tal" of the sphenoid.

nistes ont huppentheil des Schläfenbeins" (in fishes, reptiles and er gives untere Abtheilung des Schläfenflügels (in monotremes), one in fish "Felsentheil desselben (os petrosum)," Bojanus.

by Geoffr eine Flügel des Keilbeins," Bojanus; "Vordere Schla- " Köstlin.

le qui rep bein, Köstlin.

193. Bu toideum, Bojanus and Köstlin.

hyal of th transversum," Köstlin.

ntue de la elenktheil des Schläfensbein," Köstlin; "Paukenring- os. 38, 39" Bojanus.

nals by Cu menflügel des Keilbein, Bojanus.

which the fortsatz, Köstlin; Flügelbein, Bojanus.

ces."—Oss herches sur les Poissons Fossiles, 4to, t. i. 1843.

Corporis humani Fabricâ, 8vo, 1791.

	SOEMMERRING[8].
. ...	Corpus vertebræ.
rales	Arcus posterior vertebræ, seu radices arcus posterioris.
....	Radix prior seu antica processus transversi vertebræ.
....	Processus transversus vertebræ cervicalis. Costa, seu pars vertebralis, seu ossea, costæ.
s abdomi- (in abdo- a tail).	Cartilago costæ seu pars sternalis costæ; (in the abdomen) inscriptiones tendineæ musculi recti.
....	Processus spinosus vertebræ.
....	Ossa sterni et processus ensiformis; (in the abdomen) linea alba.
....	Radix posticus processus transversi vertebræ, (and) processus transversus.
....	Processus obliquus vertebræ.

der Wissenschaften zu Berlin, 1834. The terms adopted in most of the recent works of the German zootomists correspond with those of John Müller.

[7] Leçons d'Anatomie Comparée, t. i. edit. 1835.

[8] De Corporis Humani Fabricâ.

DESCRIPTION OF PLATES.

PLATE I.

In each of the figures the nos. upon the bones answer to those in the first column of Table I. and Pl. II., except where otherwise expressed.

ig. 1. Skull of a Maccaw (*Calyptorhynchus*), see pp. 41, 42, 61.

ig. 2. Skull of a Sciænoid fish, (*Pristipoma*).

ol. Foramen in nasal neurapophysis (prefrontal) for olfactory nerve.

ig. 3. Section of a skull of a Siluroid fish, (*Bagrus*).

c. Centrum of ordinary abdominal vertebra.

n. Neural arch of ditto. *c* 5. Centrum of 5th corporal vertebra.

ch'. Portion of peripheral or cortical part of the same centrum, forming the posterior aperture of the aortic canal.

n 5. Neurapophysis of the same vertebra, separately perforated by the motor and sensitive roots of the spinal nerve.

c 4. Centrum of 4th vertebra.

c 4, *ex.* External or cortical development of same centrum.

n 4. Neurapophysis, and *p* 4 parapophysis, of same vertebra.

c 3. Centrum of 3rd vertebra.

c 3, *ex.* External or cortical development of same centrum.

n 3. Neurapophysis, and *p* 3 parapophysis, of 3rd vertebra.

c x. Centrum of 2nd or axis vertebra.

c x, ex. External or cortical development of same centrum.

n x. Neurapophysis of axis. *ns, x.* Neural spine of axis.

p x. Parapophysis of axis.

c a. Centrum of 1st corporal vertebra or 'atlas.'

c a, ex. External or cortical development of same centrum.

n a. Neurapophysis of atlas separated from its centrum.

p a. Parapophysis of atlas.

c h. Anterior aperture of aortic canal, formed by the development and coalescence of the inferior cortical portions of the bodies of the five anterior vertebræ of the trunk.

c o. Centrum of occipital vertebra.

in. Internal part, and *ex* external or cortical part of the anterior prolongation of the same centrum.

n o. Neurapophysis of occipital vertebra; 2 is a continuation of the same bone, forming its otocranial plate.

ns, o. Neural spine of occipital vertebra.
c p. Centrum of parietal vertebra: it appears to consist of th denser cortical part only.
n p. Neurapophysis of parietal vertebra: the hinder figure 6 mark the otocranial plate which combines with 2, 8 (occipital par apophysis), and 12 (parietal parapophysis), in forming the chambe for the cartilaginous petrosal or acoustic capsule.
c f. Centrum of frontal vertebra, connate with *c p.*
n f 10. Neurapophysis of frontal vertebra.
ns, f 11. Neural spine of ditto.
c n. Centrum (represented by its cortical part) of nasal vertebra.
n n. Neurapophysis of ditto: it coalesces with its fellow at th median line.
ns, n. Neural spine of nasal vertebra: it coalesces anteriorly wit the centrum; closing there the neural canal.
tr. Intervertebral foramen between parietal and frontal neur apophysis, for the exit of the trigeminal nerve.
op. Foramen in frontal neurapophysis, for the exit of the opti nerve.
ol. Foramen in nasal neurapophysis, for the exit of the olfactor nerve.
The two foramina for the nerves of the epencephalic segmen are below the letters *n o*: beneath the foramina is the 'sinu auditorius.'

Fig. 4. Upper view of part of the preceding cranium: chiefly to show th modifications of the corporal parapophyses, *p* 6 to *p a*, as they ap proach the region of the cranial vertebræ: here *p o* is the occipita parapophysis; *p p* the parietal parapophysis, and *p f* the frontal par apophysis. *ns, f* the permanent fontanelle in the bifid frontal spine *pl* the occipital pleurapophysis; the letters indicate the part answerin to the tubercle of the human thoracic rib, which here bifurcates an articulates with both the parapophysis of its own segment (4) an with that of the preceding segment (8). The numbers give th special homologies of the bones, according to Table I.

Fig. 5. Section of the skull, atlas and axis of a sword-fish (*Xiphias Gla dius*).
c x. Centrum of the axis vertebra.
n x. Neurapophysis of ditto. *s x.* Neural spine of ditto.
c a. Centrum of the atlas. *n a.* Neurapophysis of ditto.
s a. Neural spine of ditto.
c o 1. Centrum of the occipital vertebra.
n o. Neurapophysis of ditto. *n s o.* Neural spine of ditto.
p o. Parapophysis of ditto. *c p* 5. Centrum of parietal vertebra
n p. Neurapophysis of ditto. *c f* 9. Centrum of frontal vertebra
n f. Neurapophysis of frontal vertebra. *f.* Medullary part of ditto.
c n. Centrum of nasal vertebra. *ns, f.* Neural spine of fronta vertebra.
n n. Neurapophysis of nasal vertebra, which, by its cellular struc ture, resembles that, called ethmoid, in mammals.
ns, n. Spine of nasal vertebra.

Fig. 6. Occipital and five following vertebræ of *Fistularia tabaccaria.*
c 5. Centrum of fifth corporal vertebra.
p 5. Parapophysis of ditto.

p. Diapophysis of ditto.
n f. Neural spine of ditto.
c 4, *c* 3, *c x*, *c a*. Elongated and immoveably articulated centrums of four anterior corporal vertebræ.
p 4, *p* 3, *p x*, *p a*. Similarly modified parapophyses of ditto.
n 4, *n* 3, *n x*, *n a*. Similarly modified neurapophyses and spines of ditto.
c o. Occipital centrum; by a rare exception in the class of fishes this presents a convex articular surface to the atlas.
n o. Occipital neurapophysis. *ns, o.* Occipital neural spine.
p o. Occipital parapophysis.

Fig. 7. Skull and anterior trunk-vertebræ of the loach (*Cobitis*).
pl 5. Pleurapophysis of fifth vertebra of the trunk.
s 5. Neural spine of ditto.
pl 4. Pleurapophysis of fourth vertebra.
s 4. Neural spine of ditto.
p x, *pl x* and 3. Pleurapophyses and parapophyses of third and second vertebræ of the trunk, anchylosed and expanded to contain and protect the air-bladder; being modified, like the parapophyses of the occipital and parietal vertebræ, in relation to the organ of hearing.
n 3. Neurapophysis of third trunk-vertebra.
s 3. Spine of ditto.
s x. Spine of axis or second trunk-vertebra.
c a. Centrum of atlas.
n a. Neural arch of ditto.
m, n. Ossicles discovered by Prof. Weber, which bring the tympaniform air-bladder into communication with the acoustic labyrinth.

The great fontanelle or foramen between the bifid spine (7, 7) of the parietal vertebra is the homologue of the small hole in the parietal bone of many saurians, called 'foramen homianum.'

PLATE II.

This Plate includes diagrams of the ideal pattern or archetype of the vertebrate endoskeleton, and of the modifications of it characteristic of the four great divisions of the vertebrate subkingdom, viz. fishes, reptiles, birds, mammals, and of man.

In each figure the parts or 'elements' of the four anterior segments—the seat of the chief modifications in relation to the lodgment of the brain, the action of the jaws and tongue, and the interposition of the sense-organs—are numbered as in the column of *Nomina* in the Plate, and as in the first column of the Table of Synonyms, No. 1.

As the four anterior segments of the neural axis are called collectively 'brain' (*encephalon*), so the four corresponding segments of the vertebral axis are called collectively 'skull' (*cranium*). The head therefore is not otherwise a repetition of the rest of the body, than insofar as each segment of the skull is a repetition or 'homotype' of every other segment of the body; each being subject to modifications which give it its individual character, without obliterating its typical features. So neither are the 'arms' and 'legs' repeated in the head in any other sense than as the cranial segments may retain their diverging appendages. The 'fore-limbs' are actually such appendages of the occipital vertebra, which undergo modifications closely analogous to those of the appendages of the pelvic segment or 'hind limbs.' And inasmuch as in one class the pelvic appendages, with their supporting hæmal arch, are detached from the rest of their segments, and subject to changes of position (fig. 2, V, V', V''), so also in other classes the appendages of the occipital segment are liable to be detached with their sustaining hæmal arch, and to be transported to various distances from their proper centrum and neural arch.

The head therefore is not a virtual equivalent of the trunk, but is only a portion, *i. e.* certain modified segments, of the whole body.

The jaws are the modified hæmal arches of the first two segments; they are not 'limbs' of the head.

The different elements of the primary segments are distinguished by peculiar markings:—

the neurapophyses by diagonal lines, thus:—

the diapophyses by vertical lines:—

the parapophyses by horizontal lines:—

the *centrum* by decussating horizontal and vertical lines:—

the pleurapophyses by diagonal lines:—

the hæmapophyses by dots:—

the appendages by interrupted lines:—

the neural spines and hæmal spines are left blank.

In certain segments the elements are also specified by the initials of their names, as in the third segment in fig. 1, and the fourth in fig. 2, for example:—

ns is the neural spine.
n is the neurapophysis.
pl is the pleurapophysis.
c is the centrum.
h is the hæmapophysis.
hs is the hæmal spine.
a is the appendage.

Fig. 1. Ideal pattern or archetype of the vertebrate endoskeleton, as shown in a side view of the series of typical segments or 'vertebræ' of which it is composed, with the commencement indicated at the two ends of those modifications, which, according to their kind and extent, impress class-characters upon the type.

The four anterior neurapophyses, 14, 10, 6, 2, give issue to the nerves, the terminal modifications of which constitute the organs of special sense.

The first or foremost of these is the organ of smell (18, 19), always situated immediately in advance of its proper segment, which becomes variously and extensively modified to inclose and protect it.

The second is the organ of sight (17), lodged in a cavity or 'orbit' between its own and the nasal segment, but here drawn above that interspace.

The third is the organ of taste, the nerve of which (gustatory portion of the trigeminal) perforates the neurapophysis (6) of its proper segment (*vertebra, parietalis* seu *gustatoria*), or passes by a notch between this and the frontal vertebra, to expand in the organ which is always lodged below in the cavity called 'mouth,' and is supported by the hæmal spine (41, 42) of its own vertebra.

The fourth is the organ of hearing (16), indicated above the interspace

etween the neurapophysis of its own (occipital) and that of the antecedent
parietal) vertebra, in which it is always lodged; the surrounding vertebral
ements being modified to form the cavity for its reception, which I have
alled 'otocrane.'

The mouth opens at the interspace between the hæmal arches of the an-
terior and second segment; the position of the vent varies (in fishes), but
always opens behind the pelvic arch (Pv) when this is ossified.

Outlines of the chief developments of the dermoskeleton, in different ver-
tebrates, which are usually more or less ossified, are added to the endoskele-
tal archetype*; as, *e.g.* the median horn supported by the nasal spine (15) in
the rhinoceros; the pair of lateral horns developed from the frontal spine
(11) in most ruminants; the median folds (DI, DII) above the neural
spines, one or more in number, constituting the 'dorsal' fin or fins in fishes
and cetaceans, and the dorsal hump or humps in the buffaloes and camels;
similar folds are sometimes developed at the end of the tail, forming a 'cau-
dal' fin, C, and beneath the hæmal spines, constituting the 'anal' fin or fins,
A, of fishes, or the subcaudal dermo-adipose tumour of the Cape-sheep.

Fig. 2. Typical skeleton of a fish (class *Pisces*). The plane of the
anterior hæmal arch (20, 21, 22) is here raised to parallel with the axis of the
trunk, and its apex or spine (22) is modified and developed so as to articu-
late with the neural spine (15) of the same segment, which thus becomes
closed anteriorly; both 22 and the hæmapophysis 21 are developed down-
wards and backwards in relation to the protractile and retractile motions of
the arch; and for the purpose of associating these motions with correspond-
ing ones of the succeeding hæmal arch, the diverging appendage is subdi-
vided (23 and 24) and developed so as to articulate with the pleurapophysis
(28) of the next arch; a rudiment of an appendage (26) is attached in some
fishes to the hæmapophysis (21) of the nasal segment, but it will be observed
that no new element is added to the hæmal arch; and, although the *Lepi-
dosteus* offers an exceptional instance of subdivision of the pleurapophysis
(21), that kind of modification is usually restricted to the diverging ap-
pendage.

In the next segment the hæmal arch has been the seat of unusual growth,
but retains more of its normal position and attachments. Its weight and
that of the appendages it supports have required an extension of the proxi-
mal articulation of its pleurapophysis (28 *a*) from its proper parapophysis (12)
backwards to the next parapophysis (8); and the pleurapophysis itself is
subdivided into two, three, or four overlapping pieces for the final purpose
explained in p. 112; but it is evident that no new element has been intro-

* I have used this word here, and in the 'Report of the British Association for 1846,' p. 169, 241, in the sense which it bears in such classical works of our own language as Glanville's Scepsis and Watts's Logic, and agreeably with its definition in Johnson's and other dictionaries, as the original or pattern of which any resemblance is made: and as equivalent to the terms 'general type' and 'fundamental type' as they occur in my "Lectures on the Vertebrate Animals," 8vo. 1846, p. 41, and *passim*.

In the 'Comparative Osteology' of Joseph Maclise, Esq., in which the author's views of the homologies of the bones of the trunk are illustrated by fifty-four beautiful plates, many of which are peculiarly well adapted to convey clear ideas of those relations in the human skeleton, the word 'archetype' is used as synonymous with 'unity.' "Unity under metamorphosis is an archetype plus quantity, being subjected to the law of proportion. Unity and the archetype may hence be regarded as one and the same thing, consequently the metamorphoses and proportionals are also understood as the products of unity or the archetype."—Remarks on plate 15. And again the author says, "Unity, or the archetype, is a name which may be applied to characterise that whole structure which is capable of undergoing metamorphosis or subtraction through all degrees of quantity severally equal to all those proportional forms which stand in series with itself."—Remarks on plate 16.

duced, because the extremities of the subdivided pleurapophysis (28 *a* and 28 *d*) retain their normal connections, the one with the parapophysis (12), the other with the hæmapophysis (29, 30). This element is also subdivided, for the same final purpose as the pleurapophysis; and its squamous union with the hæmal spine (32) is retained. Yet the connections of 29 with the condyle of the pleurapophysis and of 32 with its fellow, forming the free apex of the inverted arch of the second segment, show that the complexity is the result of mere (teleological) subdivision, and that no new part has been added to the typical elements as exhibited in the archetype* (fig. 1, 29–32); every anatomist has recognised the bones so numbered in the fish as the homologue of the single (undivided or anchylosed) bone forming the lower jaw (29–32) of the mammal (fig. 5) and of man (fig. 6). In addition, therefore, to change of shape and proportion, the parts of the archetype may be modified by division and subdivision. And in this respect the pleurapophyses (28) and hæmapophyses (29, 30, 31) of the fish deviate further from the archetype than the same parts do in the warm-blooded vertebrates. Herein is manifested the early divergence to a special form for the lowest class, which the higher classes do not assume in passing towards their own types. The diverging appendages are the seat of such excess of subdivision with special development of the divided parts, as best to countenance the idea of a superaddition of new parts to the typical element; yet the most essential character of the diverging appendage is retained under its extremest modification, as where it forms the wing of the bird or the arm of man; viz. its connection by one extremity to a hæmal arch, and the free projection of the opposite subdivided extremity, carrying out with it a fold of integument. With regard to the diverging appendage of the hæmal arch of the second segment, its modifications are arrested at different stages of departure from the simple archetypal form (34–37, fig. 1), as explained at pp. 66 and 112. The most common modification in bony fishes is that shown in fig. 2, where it is divided into two segments, and the second segment into three pieces (35, 36, 37), usually broad and flat, for the office explained at p. 112.

The parietal segment, or third counting backwards, has the hæmal arch (38–41) detached from its proper supporting parapophysis (8) by the backward development of 28 *a* of the preceding segment. This is the first example of another modification, viz. that of dislocation, sometimes accompanied by great change of place, which has tended most to obscure the essential nature of parts, and their true relations to the archetype. The principle of subdivision still manifests itself in the elements of the hæmal arch, especially in its spine, 41–43; and in a greater degree by a vegetative repetition of the 'appendage' (44), without departure from its primitive ray-like form.

The pleurapophysis of the occipital segment (50, 51) is divided into two, and its proximal end is usually bifurcate in fishes, articulating like the normal ribs of higher animals, by a 'head' and a 'tubercle' to two points of the neural arch of its segment.

Almost every stage of development and departure from the primitive type is manifested by the diverging appendage (54–57) up to the extent of modification attained by the typical osseous fish. The proximal segment is divided into two pieces (54 and 55), the next segment into four or more (56), and the last segment into a greater but variable number of pieces, retaining the elementary form of rays.

The Lepidosiren (fig. 7) is eminently instructive by the retention in the occipital vertebra of the primitive condition of the appendage, as shown in the archetype (fig. 1, 53–57), modified only by segmentation of the ray. The

* See note, p. 177.

pleurapophysis of the arch (51) likewise retains its simple cylindrical form, and is articulated to its centrum, like the other ribs of the Lepidosiren, by an undivided head.

The hæmal arch of the fifth segment (first of the trunk) is commonly detached from its centrum and neural arch in fishes, without being displaced backwards. The pleurapophysis (*pl*) is short and simple, sometimes expanded; the hæmapophysis (58, *h*) is simple, long and slender. When this arch supports an appendage it is a simple diverging ray.

All the succeeding abdominal segments of the fish have their hæmal arches incomplete by bone; the hæmapophyses and spines retaining the primitive fibrous condition. The pleurapophyses of most support diverging appendages in the form of simple undivided bony rays.

A part of the hæmal arch of a post-abdominal (pelvic) segment is ossified (63), and supports a more complex appendage (69) in the form of one, two or more jointed rays, which project beyond the surface and are enveloped by a fold of skin forming the 'ventral' fin, V, making a pair with the one on the opposite side. This partially ossified hæmapophysis articulates with its fellow by its anterior apex, forming a 'symphysis ischii' seu 'pubis'; and, in some fishes called 'abdominal,' it is connected to its proper pleurapophysis (62) by an aponeurosis representing its unossified continuation.

The remarkable degree to which one and the same part may be subject to the modification of change of position, is strikingly exemplified in this lower portion of the pelvic arch with its appendages in fishes. It may be moved forwards, so that the symphysis of the pelvic arch is brought into connection with that of the scapular arch; when, according to the length of the ossified parts of the pelvic hæmapophyses, the species is either 'thoracic,' as when the ventral fins are at V′, or 'jugular,' when they are advanced to V″. The universally acknowledged and long recognised special homology of the hæmal arch and appendages of the pelvic vertebra, as the 'ventral fins' of fishes, under these changes of position, prepare us for the recognition of an analogous modification of the hæmal arch and appendages of the occipital vertebra in the higher classes of vertebrata.

Beyond the abdomen the osseous and aponeurotic parts of the hæmal arches rapidly contract; the progressively elongated parapophyses usually bend down and complete the inverted arch by their apical coalescence; sometimes distinct pleurapophyses continue to form these arches; sometimes these elements may be traced, anchylosed with their fellows of the opposite side, and with the coalesced extremities of the parapophyses. The bodies of a certain number of the terminal segments coalesce together in the typical osseous fishes, and support several neural and hæmal arches and spines, usually more or less expanded, and forming the basis of the caudal fin, C.

The ossified parts of the dermal median and symmetrical folds, constituting the dorsal (D I, D II), the anal (A), and caudal (C) fins, are added to the endoskeleton in fig. 2; *in* are the interneural spines; *dn* the dermoneural spines; *ih* the interhæmal spines; *dh* the dermohæmal spines; these form no part of the true vertebral skeleton, and are peculiar to fishes. The diagram of the modified cranial segments is not complicated by the outlines of the sense-capsules or mucodermal bones; the latter are shown in fig. 2, 72, 73, Plate I.

Thus, compared with the archetypal figure, the endoskeleton of the fish deviates by excess of development, manifested chiefly in the diverging appendages of the four anterior or cranial segments, and by arrest of development in most of the other segments; but the principle of polaric or vegetative repetition greatly prevails, and more of the segments resemble one another than in any of the higher classes.

Fig. 3. The Crocodile is here taken as the type of the class *Reptilia*.

The hæmal arch of the anterior segment is now firmly fixed by excessive development, chiefly of its hæmapophyses (21), which have extended their attachments to all the elongated elements (13, 14 and 15) of their own neural arch. The diverging appendage (24) from the pleurapophysis (20) fixes the arch extensively to the centrums of the second and third segments: the appendage from the hæmapophysis (21) bifurcates; one branch, divided into two pieces (26 and 27), connects the arch with the pleurapophysis (28) of the next segment; the other branch (25) extends the attachment to the parapophysis (12) of the same segment, and also to the appendage (24) of its own arch.

The pleurapophysis (28) of the frontal segment is undivided; it is represented as displaced and depressed; but in nature it still retains a small par of its connection with its proper pleurapophysis (12), although it is develope backwards so as chiefly to articulate with that (8) of the following seg ment: it supports no diverging appendage. The hæmapophysis (29–31 is more subdivided than in fishes, in relation to functions explained in pp 122, 123.

The excess of development of the hæmal arch of the frontal vertebra i compensated by the defect of development of that of the parietal one (40 41); and this constitutes the next great additional step in the deviation fron the archetype. Only the hæmapophyses (40) are ossified: the hæmal spine though much expanded and flattened, remains cartilaginous, and the pleur apophysis is represented by a feeble ligament. The whole arch is detached an displaced backwards, and its diverging appendages cease to be developed.

The tendency to retrogradation manifested by the preceding hæmal arche is carried out to a striking extent in that (51, 52) of the occipital segment (th fourth counting backwards): it overlaps the homotypal arches of the 8th t the 11th segments of the trunk: the ossified portions of both its constituen element, 51 and 52, are simple; the hæmal spine 52′ is prolonged backward. The diverging appendage manifests, in comparison with that in the fish, a additional segment (53), which is single; the segment of two pieces (54 an 55) is now the second. The rays of the distal segment are reduced to fiv in number, which is never afterwards exceeded in the vertebrate subking dom. The dislocation and retrogradation of the posterior hæmal segmen of the skull form the second chief additional feature of departure from th archetype, as compared with the skeleton of fishes. The third well-marke modification is the development of an inferior (cortical) portion of the bod of the atlas (*ca, x*), distinct from the main part of that centrum (*ca*), whic coalesces with that of the axis, and is commonly called its 'odontoid' pro cess (see p. 93).

The nine segments that succeed the head resemble those of fishes in th non-ossification of the hæmapophyses and hæmal spines, but deviate furthe from the archetype by the minor development of the pleurapophyses. The progressively elongate to the 12th vertebra, where the hæmal arch is com pleted by a hæmapophysis and hæmal spines.

The hæmapophyses are not so completely ossified as the pleurapophyse and they are divided from these by the interposition of cartilaginous piece *a a*; these pieces may be regarded either as dismemberments of the hæm apophyses, or as unossified parts of the pleurapophyses. The divergin appendages (*a, a*) are usually cartilaginous.

Beyond the 21st segment of the trunk* the pleurapophyses usually ease to be represented either by bone or cartilage: but the partially ssified hæmapophyses are continued to those of the pelvic segments, 61 nd 63, *h*. In these segments the pleurapophyses reappear, and are di- ided into two parts, like those in the thorax: the proximal portions (*pl*, *l*) are short and thick; the distal portions have either coalesced into one road and thick plate (62 *pl*), or the distal portion of one pleurapophysis still more remarkably developed and takes the place of two: this question discussed at pp. 160, 161. The two hæmapophyses (63, 64) are distinct nd well-ossified. The diverging appendage (65–69) has been subject to he same kind and amount of development as that of the scapular arch 53–57). The first steps in the progression of this metamorphosis from the rimitive type is shown in the *Lepidosiren* (fig. 9), and the *Proteus* (fig. 10). 'he modification of the pelvic segments and their appendages in the reptile orms another prominent feature of deviation from the archetype. The leurapophyses are continued, progressively shortening, attached to the iapophyses of a certain number of the vertebræ that succeed the sacrum: he hæmapophyses are no longer attached to their extremities but are directly rticulated to the central elements, with a slight degree of displacement, whereby they articulate to another segment as well as to their own. The node and degree of departure from the archetype are now such that dif- erent series of vertebral segments may be classed into groups, with di- tinctive characters and names:—

The first four segments, by the fixed union of their neural arches, as *cranial* Cr), under the collective name of 'skull.'

The next nine segments, moveably articulated, and with free or 'floating' leurapophyses, as *cervical*, C, forming collectively the region called 'neck'.

The succeeding nine segments with ossified and moveable pleurapophyses nd hæmapophyses, as *dorsal*, D, forming the 'back,' 'thorax' or 'chest.'

The three following moveable vertebræ, without free bony pleurapophyses, s *lumbar*, L, forming the 'loins.'

The next two vertebræ, immoveably united, and with modified and much- eveloped hæmal arches and appendages, are called *sacral*, and collectively pelvis and hind limbs.'

All the other segments are '*caudal*' and constitute the 'tail.'

The hæmal arch (51, 52) with the developed appendages (53–57 *a*) detached rom the occipital vertebra, may require to be specially noticed in this sum- nary of the parts of the endoskeleton, as from the circumstance of its com-

* According to Cuvier, the pleurapophyses cease to appear after the 20th trunk-vertebra n the *Crocodilus biporcatus*, and after the 19th in *Alligator lucius*. I allude to these dif- erences for the purpose of remarking that the conformity of organization is greater than vould appear at first sight from the formulæ of the vertebræ of the different species of rocodile cited in the Table at p. 220, tome i. Leçons d'Anatomie Comparée, 1835. The number of vertebræ from the atlas inclusive to the sacrum is the same in each species, as vill be seen by the following extract:—

	Cervical.	Dorsal.	Lumbar.		
Crocodile à deux arêtes	7	13	4	=	24
Crocodile du Gange	7	14	3	=	24
Caiman à mus. de brochet	7	12	5	=	24

The difference in the dorsal and lumbar series depends merely on the ossification or therwise of the pleurapophysial tendons or fibrous basis attached to the diapophyses of the 20th, 21st and 22nd vertebræ.

A slight change in the form and size of the pleurapophysis is all that distinguishes the irst dorsal from the last cervical vertebra in the Cuvierian Table.

monly remote position from its proper segment, it may not have been thought of as a part included in the first class of vertebræ constituting the skull.

Many striking and extreme deviations from the archetype are manifested in the skeleton of the more aberrant forms of the reptilia. The number of moveable trunk-segments is reduced to the minimum in the *Batrachia* (*e.g.* 7 in *Pipa*), and increased to the maximum in the *Ophidia* (422 in *Python*). At first view the principle of vegetative repetition seems to have exhausted itself in the long succession of incomplete vertebræ which support the trunk of the great constrictors: but by the endless combinations and adjustments of the inflections of their long spine the absence of locomotive extremities is so compensated that the degraded and mutilated serpent can overreach and overcome animals of far higher organization than itself: it can outswim the fish, outrun the rat, outclimb the monkey, and outwrestle the tiger; crushing the carcase of the great carnivore in the embrace of its redoubled coils, and proving the simple vertebral column to be more effectual in the struggle than the most strongly developed fore-limbs with all their exquisite rotatory mechanism for the effective and varied application of the heavy and formidably armed paws. And whilst the vertebral column of the ophidian order exhibits the extreme of flexibility, that of the chelonia manifests the opposite extreme of rigidity: back, loins and pelvis constitute one vast sacrum, or rather abdominal skull, but a skull subordinated chiefly to the lodgment and defence of a much-developed hæmal system, and in which the pleurapophyses, hæmapophyses and their spines repeat the same modification of great expansion and fixed union by marginal sutures, which the neurapophyses and spines undergo in the cranium of the higher vertebrates. The well-known determination of the ordinary elements of the typical vertebra in the thoracic-abdominal segments of the tortoise need not here be discussed (see pp. 100, 101): but it is, perhaps, worthy of repetition that the neurapophyses exhibit the modification of change of position, like that which has been described in the sacrum of the bird; being shifted from their own centrum over one half of the next centrum, thus adding to the strength and elasticity of the whole osseous vault (see p. 95). The confluence of the neurapophysis (14) with its own moiety of the neural spine (15) has already been noticed (p. 124) in the anterior segment of the cephalic skull of most chelonia. I may here add that the typical condition of the hæmal (maxillary) arch of the same segment is well shown in the *Emys expansa*. The pleurapophyses (palatines) meet at the base of the cartilaginous vomer, above and behind the posterior nares, sweep outwards and downwards, give attachment to the hæmapophyses (maxillaries) which advance and converge, and the arch is closed below the nasal passage by the hæmal spine (premaxillary). Cut through the junction of the hæmapophyses with the neurapophyses (prefrontals), and with the diverging appendages (malars), and the inverted arch is then suspended by its proper piers, the pleurapophyses or palatines.

In the connation or coalescence of the neurapophyses and spines forming the parietal and frontal neural arches in the ophidian and some chelonian reptiles, we perceive a return to the common constitution of those arches in the vertebræ of the trunk, in which the permanent separation of the neural spine from the neurapophyses occurs as a rare exception.

In the class-skeleton (*Aves*) represented in fig. 4 the archetype is further departed from than in the typical reptilia; and when the general form of this diagram is contrasted with that of the first figure, the power of demonstrating the fundamental agreement which reigns throughout, and which is equally manifested in the comparison of figure 4 with those of the piscine and reptilian skeletons, affords a most striking proof of the unity of plan which pervades the whole series.

As compared with the crocodile (fig. 3) the proportions of the hæmapophysis (21) and spine (22) of the anterior segment are reversed; there is a return towards the condition of the parts in fishes (fig. 2); the strength of the arch being chiefly due to the great development and extensive connections of 22, which usually sends a process upwards and backwards between the divided neural spine (15) of its own to that (11) of the next segment. The pleurapophysis (20) has often a slender rib-like form, and the appendages retain the form of bony rays. That (24) from the pleurapophysis is simple; that (26, 27) from the hæmapophysis is divided in the embryo-bird: both concur in attaching the hæmal arch of the anterior segment to the pleurapophysis of the second segment. The neurapophyses of the anterior segment coalesce and form a single vertical bone, slightly expanded above and sometimes appearing anterior to the frontal.

The hæmal arch of the second segment is detached from its neural arch; and, although its proper parapophysis (12) sometimes joins the next one (8), yet this exclusively supports, in birds, the pleurapophysis (28) of the frontal segment. The hæmapophysis is developed, as in the reptile, from several centres (29, 29′, 30′, 31), but these coalesce with each other and with the hæmal spine, 32, to form the single bone called lower jaw in most birds.

The hæmal arch (40–46) properly appertaining to 8—the parapophysis of the parietal segment—is detached from it, and freely suspended, somewhat retrograded in position beneath the next segment: its development has suffered as marked an arrest as in the crocodile.

The hæmal arch, with its appendages of the hindmost segment of the skull, is displaced backwards to a greater extent than in the reptile.

The pleurapophysis, 51, retains the form of a long, flat, slightly-arched rib: the hæmapophysis (52) is straighter and stronger. There are birds (*Apteryx*, e. g.) in which this arch is arrested at almost as early a stage of growth as is the antecedent (hyoid) arch of the skull. The elements of the neural arches of the skull, 1–15, early anchylose together in most birds, with the exception of the centrum (13) of the foremost segment, which more commonly coalesces with the pleurapophyses (20) of its hæmal arch.

The size of the brain now demands a modification of the neural arches superadded to those which they present in the cold-blooded vertebrates, and occasions a marked difference in the form of the skull: it is important to note how this is obtained. The nature of the modification is well shown in the young of those large birds which are devoid of the powers of flight. No new bone is introduced to increase the cranial walls and give the cavity its due capacity; this is gained by excess of growth of common and constant elements; and, as has been shown in pp. 126–128, those furthest from the centrum (3, 7, 11) are the chief seat of such excess. With regard to the neural spines of the frontal and parietal vertebræ, it is accompanied by a temporary bipartition, the ossification commencing from two lateral centres in each; but the halves soon coalesce with each other and with their sustaining neurapophyses (2, 6, 10).

In those segments which, from the brevity and free termination of the pleurapophyses, may be called 'cervical,' the elements of the neural arch and also the pleurapophyses early anchylose together in each segment, converting it into the single bone, called in comparative osteology a 'vertebra,' and these vertebræ are remarkable for their great number in most birds; and consequently the neck is as remarkable for its great length and flexibility. The detached hæmapophyses (53) of one of these vertebræ, (which vertebra, by the analogy of the fish (fig. 2, 58), should be the *atlas*,) commonly coalesced together at their distal ends forming a bony arch, like a slender edentulous lower jaw, have followed the hæmal arch of the occipital vertebra (51, 55) in its retrograde course, though not quite to the same extent. These mutually anchylosed hæmapophyses (53) forming the bone, called 'furculum' in ornithotomy, are generally the only pair of ossified cervical hæmapophyses. If, however, we define the cervical vertebræ, as in the crocodile, by their mobility and the free termination of their pleurapophyses, we may then recognise in some birds the detached hæmapophyses of the last cervical vertebra attached, as at *h*, to those of the succeeding segment: this structure may be observed in the common goose (*Anser palustris*). The pleurapophyses of the posterior cervical vertebræ are free, and rapidly elongate. The hæmapophyses of the segments with complete hæmal arches are bony, and are commonly defined as 'sternal ribs', their pleurapophyses being called 'vertebral ribs,' agreeably with the restricted anthropotomical meaning of the term 'vertebra.' These pleurapophyses support bony appendages (*a a*), which serve, like those of the foremost hæmal arch of the skull, to connect their own arch to the next and associate them together in movement*. After six or seven segments with these typical hæmal arches come others with shorter pleurapophyses terminating freely, not reaching their hæmapophyses, one of which, ossified, is shown in the diagram at *h'*, adhering by its distal end to the preceding hæmapophysis and terminating freely above. These 'floating sternal ribs' are more numerous in the crocodile (fig. 3, *h'*). The hæmal spines of the dorsal segments with complete hæmal arches, become the seat of the most extensive and characteristic modifications of the avian type of skeleton. They are greatly extended in breadth, and, like the correspondingly expanded neural spines of the cranial vertebræ, are developed from two lateral moieties; but the individual spines, indicated by dotted lines in the diagram (60), are not ossified from separate centres, but continuously, so that the hæmal spines of six or eight vertebræ are at first represented by a pair of osseous plates. A cartilage is usually extended vertically from their median junction, which, when ossified, forms a strong crest or 'keel' (60'). The hæmal spine of the scapular arch (52') is sometimes ossified from a proper centre; as is also a piece prolonging the series posteriorly: but all soon coalesce into one bone called 'sternum.' The anterior portion, 52'. has received the name of 'episternum', the median keel, 60', that of 'entosternum,' the posterior piece, which sometimes remains cartilaginous, that of 'xiphisternum.' In the terrestrial birds incapable of flight the keel or 'entosternum' is not developed: in the rest of the class the extent of this part and of the ossified portion of the body of the sternum bears a direct ratio to their power of flight; the peculiar modification of these extreme elements of the dorsal segments being governed by the size of the muscles moving the wings.

The next great deviation from the typical standard, peculiar to birds, is the great extent of the vertebral axis which is embraced by the enormously developed pelvic pleurapophyses, 62, and the unusual number of segments which, being thus deprived of reciprocal motion, grow together and form, according to this character, the bone or region called 'sacrum.' In investigating the structure of this part of the endoskeleton in the embryo-bird, the neural arches are found to manifest a change of position analogous to,

* These appendages are not the result, as has been supposed, of a bifurcation of the vertebral rib: they are independent pieces originally in all birds, and retain their individuality in some, *e.g.* apteryx, penguin, with proper muscles for their elevation and depression—potential homotypes of the flexors and extensors of more developed limbs.

though less extensive than, that of certain of the hæmal arches of more anterior segments (51–52, *e. g.*): the results of this analysis are fully detailed at pp. 95 and 159. Most of the pleurapophyses of the sacral vertebræ are stunted in their growth, which may literally be said to be stopped by the pressure upon their extremities of the overgrown distal portion of one of their homotypes, forming the bone called 'ilium' (62, *pl*). But one or two of the pleurapophyses at the anterior part of the series (*pl*) escape from beneath the 'ilium' to terminate freely at some distance below it: these are usually bifurcate at their proximal ends, and moveably articulated to their anchylosed centrums and diapophyses: the shorter anchylosed sacral pleurapophyses have simple proximal ends and articulate in the embryo to the interspace between their own and the adjoining centrum, as shown in the cut 27, *pl.*, to which they soon become anchylosed.

The contemplation of the modifications of the different natural segments in the trunk of the bird, particularly the freedom of some elements and the fixation of others, strongly impresses on the mind the purely artificial character of the regions of the spine which have been transferred from anthropotomy into the anatomy of the vertebrate animals. Thus Cuvier declares, "Il n'y a point de vertèbres lombaires proprement dites*." And a later author:—"Die Wirbel zerfallen in Hals- Rücken- Kreuzbein- und Stusswirbel; eigentliche Lendenwirbel sind gewöhnlich nicht zu unterscheiden."

Cuvier's negation of proper lumbar vertebræ in birds of 1799 is reproduced in succeeding systems and handbooks of comparative anatomy down to the latest by Siebold and Stannius, *e. g.* of 1846. But the student of anatomy in its wider acceptation will understand that the segments homologous with those included under L in fig. 3, are by no means wanting in fig 4, but only otherwise modified.

It may be regarded as highly probable at least, from the striking points of agreement which are observable in the organization of the crocodile and of the bird, that, counting backwards from the first 'dorsal' in figs. 3 and 4, the next twenty segments are homologous in both. But, in the bird, those that answer to the three or four last dorsal vertebræ in the crocodile are anchylosed together, and the last of these had its pleurapophyses modified to form abutments against the elongated ilia. The next three segments, answering to the lumbar in the crocodile, are modified as in the last 'dorsal.' The two following segments similarly modified will answer then to the two sacral vertebræ of the crocodile, and anchylosis extends backwards so as to include two or three vertebræ homologous with the anterior caudals in the crocodile. This appears to be the true interpretation of the enormous 'sacrum' of the bird; it is not merely 'lumbo-sacral' but 'dorso-lumbo-sacro-caudal', including as it does representatives of each of those classes of vertebræ in the crocodile, but which have lost the artificial characters that distinguished them in that nearest allied existing vertebrate. The special homologies are indicated by the letters D, L and S.

The characters of the regions of the vertebrate skeleton are, as already remarked in reference to the crocodile, artificial, and are used for the sake of convenience in describing and comparing the vertebræ of different species. Those, therefore, are the best which are the most constant and most readily applicable in any given class. Proceeding to assign such to the bird, as in the crocodile, unbiassed by anthropotomical characters of the vertebral regions, all those may be called 'cervical' in the bird that extend from the skull to the first vertebra with the hæmal arch complete, and those dorsal

* Cuvier, Leçons d'Anatomie Comparée, i. (Ed. 1799, p. 170; Ed. 1836, p. 205).

that extend from that vertebra inclusive, to the first vertebra embraced by, and anchylosed to, the iliac bones. One usually finds in the falcons, the gallinaceous birds and in some waders, five or six of the centrums and neural arches of the dorsal vertebræ anchylosed into one mass, a single free centrum usually intervening between this mass and the true sacrum. Some comparative anatomists call that cervical vertebra the 'first dorsal' in which the pleurapophyses retain, or begin to regain, their moveable articulations: but this character varies in different individuals of the same species. I have even found the pleurapophysis of the last cervical vertebra anchylosed on one side and not on the other.

The retention by the pleurapophyses of moveable articulations with the centrum, might also seem a good character of dorsal vertebræ at the hinder end of the series; but it is inconstant: I have found those elements anchylosed in one individual and free in another of the same species, in the anterior vertebræ, which are sacral by coalescence. All those vertebræ may be called for convenience 'sacral' in the bird, which are confluent by both centrums and neural arches with each other and with the iliac bones; and this confluence is so complete that it usually requires a vertical section and reference to the nerve-outlets in order to determine their number. The free vertebræ that succeed these are the caudal, of which the last, as in most osseous fishes, is a coalesced congeries of several, though for convenience, counted as one, and called in ornithotomy the plough-share bone (*c, n, h*). Although so many segments of the bird's skeleton are modified to transfer the weight of the horizontal trunk upon the ilia (62), the 'pelvis,' as in the crocodile, has but two hæmapophyses, 63, 64, below: it is characteristic of birds, however, that these are not united at their distal ends to their fellows of the opposite side, either with or without the intervention of a hæmal spine. The exception which the ostrich offers in regard to the anterior pair (pubic bone, 64) and that which the rhea presents in respect to the posterior pair (ischia, 63), serve to prove the rule of the inferiorly open pelvis in birds.

In regard to the diverging appendages of the two hæmal arches (scapular and pelvic) which have been selected for development into locomotive organs in all classes of vertebrata, the corresponding segments (carpal, 56, and tarsal, 68) agree in the paucity of their divisions, two bones in each, in all birds; and the succeeding segments (metacarpal and metatarsal) in consisting of three coalesced bones in both wing and leg, supporting digits answering to those marked II, III and IV, *ii*, *iii*, *iv*, in the crocodile. Such at least is their general character, the minor differences being the following:—In the hand-segment of the wing the anchylosed metacarpal of digit II is very short, represented as it seems only by its proximal end; those of the digits numbered III and IV attain their normal length, and are anchylosed together at the extremities only, with an interspace between their shafts.

In the metatarsus the three homotypal bones coalesce throughout their length, except in the penguin, where interspaces are left between their shafts or middle parts. But they also coalesce proximally with the two primitively distinct tarsal bones (68), whilst the metacarpals coalesce proximally with only part of the carpal series, if at all. And to the metatarsus there is usually superadded a rudimental, but unanchylosed, metatarsal bone of the digit answering to no I in the crocodile; but directed backwards, except in the swift. The numbers of the phalanges of the toes, *i ii* and *iii* in birds, correspond with those of their homologues in the crocodile: the toe *iv* has an additional phalanx, and the regular progression of the increase from 2 to 5, with one or two exceptions, is constant in the class, and serves to determine the toes in those birds in which they are reduced to three or two: thus, in the ostrich (fig. 11), the shorter of the two toes is determined by its greater number of phalanges, 5, to be the homologue of the fourth in tetradactyle birds; and it is interesting to observe that the toe *iii*, notwithstanding its much greater length, has the usual smaller number of phalanges. But whilst unity of design is thus manifested, the wisdom of the Designer is displayed by the greater strength which results from the minor degree of subdivision of the part which takes the largest share in the support and propulsion of the body. The toe *v* is never present in birds, there is not even the rudiment of its metatarsal bone. The toe *i* is equally absent. (See paragraph at p. 193, on the spurs of the *Gallinacea.*)

Fig. 4 is the diagram of the skeleton of a typical mammalian quadruped; *e. g.* the dog (genus *Canis*). The modifications of the hæmal arch of the anterior segment resume the characters of those in the crocodile; the hæmapophysis (21) being the chief seat of development, and for the same purpose of extending its attachments, and adding to the firmness and strength of the henceforth immoveable maxillary arch. The diverging appendage from the pleurapophysis (20) is a single bone on each side (24), and in most mammals becomes confluent with the part of the posterior segment (5) against which it abuts.

The neurapophyses (14) of the anterior segment have coalesced together, as in birds, but are complicated, and their nature further obscured by anchylosis with ossified portions of the olfactory capsules, often extremely complex and extensive in the class Mammalia, in which the organ of smell attains its maximum of development. The neural spine (15), sometimes single, more frequently bifid, enjoys, agreeably with its extreme position in the series, a vast range of variety in its forms and proportions. In the rhinoceros it supports a dermal spine or 'horn.'

The second (frontal) segment presents unexpectedly a return to the archetypal character in a particular, in the absence of which all the lower classes of vertebrata depart from it, viz. the primitive independence of its centrum (9) from that (5) of the succeeding segment. The spine (11) of this, as well as those (7, 3) of the two following segments, continue, as in birds, to be the chief seat of the expansion requisite for the protection of the progressively developing brain. But in most mammals an additional element in the cranial walls is gained by the expansion of the distal end of the diverging appendage from the hæmapophysis (21) of the anterior segment. This appendage consists, as in birds and reptiles, of two pieces, and it is the second or most remote piece (27) which is the seat of the principal varieties, and especially of that squamous development which enables it not only to extend the points of fixation of the maxillary arch, but at the same time, to subserve the requirements of cranial space consequent on the large size of the cerebrum. The dismemberment called 'interparietale,' *x*, of the spine 3, has a less constant relation to the increased capacity of the cranium.

The pleurapophysis (28) of the second segment becomes, in the present class, still further displaced from its typical connections, and is even superseded in its typical functions by the intervention and development of 27. It is consequently much reduced in size, and strangely distorted in form in subserviency to the almost sole office that now remains to it, viz. the support of the tympanic membrane.

The frontal hæmapophyses and spine (29–32) have coalesced into a single bony arch, articulated by its extremities to the under part of the appendage 27.

The pleurapophysis (38) of the hyoid or third hæmal arch resumes in many mammals its typical connections with the parapophysis (8) of its proper segment; but its development is usually more or less restricted.

The articulation of the fourth (occipital) segment with the succeeding one called 'atlas,' is chiefly by means of zygapophyses (condyles) developed from the neurapophyses (2); the parapophyses (4) are likewise exogenous processes of the same elements.

The hæmal arch of the occiput (51, 52), though in close proximity with its proper neural arch in some mammals, and in all mammals at the earlier period of development, is not directly articulated thereto, and sometimes recedes far from the rest of the skull.

The hæmapophysis (52) of the arch is ossified throughout its entire extent and the hæmal spine 52′, below, in only one small exceptional order of the class (*Monotremata*). It becomes anchylosed with the pleurapophysis in all, and appears in the majority therefore as a mere process of 51.

The single pair of cervical hæmapophyses (58) are more variable, both as to their extent of ossification and even existence.

The body of the atlas continues subject to the same modification of development from two centres with coalescence of one portion with the next centrum, which characterises it in all the other vertebrates above Batrachians*.

The confluence of the centrum with the neural arch takes place in every vertebra of the trunk; and the pleurapophyses, which are very short in the seven segments that succeed the skull, here also commonly coalesce with the other elements, circumscribing the lateral foramina for the 'vertebral' arteries. With the exception of the detached bones 58, they are the only ossified parts of the hæmal arches of those segments.

The constancy of the number, *seven*, of the segments so modified, is truly remarkable and characteristic of the class Mammalia. It is true that the number is established at a very early stage of development, when the neck is alike short in all; and its law must be sought for in the circumstances, such as the existence of a complete diaphragm in the mammalia, which determined the number and distribution of the pairs of cervical nerves, upon which the development of the cervical vertebræ more immediately depends. The exceptions to the number *seven*, viz. *six* in the manatee, and *eight* or *nine* in the three-toed sloths, serve to establish the rule.

The eighth segment of the trunk in mammalia, like the tenth in the crocodile, has a complete hæmal arch, and here therefore the 'dorsal' series begins; but the hæmapophysial elements are rarely ossified in the present warm-blooded class.

The pleurapophyses (*pl*) of these arches are not only moveable, but are subject to a slight displacement, and their articulations, like those of the neurapophyses in the bird's sacrum, extend over the interspace of their own and a contiguous centrum.

The hæmal spines (60, 61, *hs*) commonly remain distinct, and form a chain of ossicles corresponding in number with the complete hæmal arches, but they coalesce with each other in some of the higher mammalia, and are called collectively 'sternum.' (See p. 158.)

As the segments recede the pleurapophyses become shorter, return to their proper vertebra, and usually become appended to its diapophyses; the hæmapophyses also become shorter, and terminate at first by abutting against their antecedents, and finally by projecting freely.

* See p. 93, and Annals of Natural History, vol. xx. p. 217.

These segments are followed by others (L) in which only the pleurapophysial parts (*pl*) of the hæmal arch are ossified, and these parts coalesce with the diapophyses (*d*).

Then come the segments (S) which, like those of the skull, are the seat of the modification by anchylosis, and of great and peculiar development of two of the hæmal arches in connection with them; the nature of the deviations from the typical standard which characterise the province of the endoskeleton called 'sacrum' and 'pelvis,' has been explained at pp. 158–161. In most mammals a greater number of segments is involved in this metamorphosis than in reptiles, in none are so many the seat of it as in birds. In the cetacea the modification by anchylosis is transferred to segments at the fore-part of the trunk, their 'sacrum' may be said to be in the neck; none of the post-abdominal vertebræ are subject to it any more than in serpents, fishes, or the extinct marine reptiles (*Enaliosauria*).

Great diversity of form, number and degree of development prevails in the vertebræ that succeed the sacrum in mammalia. Short pleurapophyses are developed at the extremities of the diapophyses of the anterior ones and coalesce with them. The hæmapophyses, when present or ossified, are articulated, as in reptiles, to the centrum directly, and alone form the hæmal arch. The terminal vertebræ are reduced to the central element, and rarely anchylose together.

The anterior anchylosed and expanded vertebræ are the cranial, Cr.

Those usually free vertebræ with short pleurapophyses, anchylosed to both their centrum and neural arch, are called 'cervical,' C. In some whales and armadilloes all or some of these vertebræ coalesce into one mass.

The series with moveable and usually longer pleurapophyses is called 'dorsal,' D.

Those with pleurapophyses confluent or connate with the extremities of the diapophyses are called 'lumbar,' L.

The succeeding vertebræ which anchylose together are called 'sacral,' S.

The rest are 'caudal,' Cd.

The modifications of the diverging appendages of the scapular and pelvic arches are numerous in kind and extreme in degree: with the exception of the cetacea, in which the hinder pair is absent—the cheiroptera, in which the fore-pair is specially developed for the actions of flight—and some burrowers, as the mole—a close analogy is commonly kept up between the two pairs: both, for example, are reduced to the same degree of simplicity in the solid-ungulous horse; both arrive at almost the highest stage of development, in the special adaptation of one of the digits to react upon the rest as an opposable thumb in both the fore- and hind-feet of the quadrumana.

Fig. 15, bones of the fore-limb, and fig. 16, bones of the hind-limb, of the wombat, illustrate the serial homology* of those bones, explained at pp. 166-168.

* It is with pleasure that I see any of the new terms proposed in my "Lectures on the Vertebrata" (1846) and "Report on the Archetype and Homologies of the Vertebrate Skeleton" (Report of the sixteenth meeting of 'the British Association held at Southampton in 1846'), and in earlier publications, as the "Geological Transactions for 1838," sanctioned by an original author like that of the 'Comparative Osteology,' folio, 1847, before cited. Thus Mr. Maclise says, "The laws of symmetry or Serial Homology preside over the genesis of formation."—Remarks on plate 49. And again:—"But in each of these three series of distinct parts, in that of spinous processes, of *neural arches*, and of bodies of vertebræ." "The spinous process, the *neural arch* and the vertebral body are structural varieties."—Explanation of plate 3. Whether the adoption of such terms as 'neural arch,' 'serial homology,' &c. be implied or acknowledged, the gratification is the same, provided they are not turned from their original sense. By 'neural arch' I mean both 'neurapophyses' and

53, 'humerus,' is the homotype of 65, 'femur.'
54, 'ulna,' is the homotype of 67, 'fibula.'
o, 'its olecranon,' is the homotype of 67′, 'fabella,' or the sesamoid bone articulated to the produced and expanded head of the fibula.
55, 'radius,' is the homotype of 66, 'tibia'*.
sc, scaphoid portion of 'os scapholunare,' is the homotype of *sc*, 'scaphoides.'
l, lunar portion of 'os scapholunare,' do. of *a*, 'astragalus.'
cu, cuneiform portion of 'os scapholunare,' do. of *cl*, articular part of 'calcaneum.'
p, 'pisiforme' is the homotype of *cl′*, fulcral part of 'calcaneum.'
t, 'trapezium' do. of *ci*, inner cuneiform.
z, 'trapezoides' do. of *cm*, middle cuneiform.
m, 'magnum' do. of *ce*, outer cuneiform.
u, 'unciforme' do. of *b*, cuboides; both of these representing two distinct carpals coalesced, as the scapholunar in the carpus represents the astragalus and scaphoid in the tarsus, and the calcaneum reciprocally the cuneiform and pisiform bones.

The serial homologies of the carpals and tarsals are better illustrated in the hand (Pl. II. fig. 13) and foot (fig. 14) of the orang, as will be presently explained.

With regard to the digits, they never exceed five in number in mammalia, and with the exception of the cetacea, the number of phalanges is limited to two in the first, I and *i*, and to three in each of the other digits, in both fore- and hind-feet. The first or innermost digit, as a general rule, is the first to disappear; in the hind-foot of the orang (fig. 14) commonly, and in that of the wombat, fig. 16, constantly, its short metatarsal supports but one phalanx; in the dog, taken as the type of the class (fig. 4), the inner digit is usually wanting in the hind-foot, and is always very diminutive in the fore-foot. The first digit of the hand is reduced to a short metacarpal in the spider-monkeys (*Ateles*).

The outer digit V and *v* is the next to disappear. In the tapir it is wanting in the hind-foot; and in the rhinoceros (fig. 17) in both hind- and fore-feet.

In the bisulcate quadrupeds the development of the second digit (II and *ii*) is arrested in addition to the two extreme ones (I and V), and the functions of support and progression are committed to the equally and symmetrically developed 3rd and 4th digits *iii* and *iv*. In most of the ruminants rudiments of the 2nd and 5th digits are retained (as at *ii* and *v*, fig. 18); but in the camel-tribe they have entirely disappeared together with the first digit, I and *i*.

'neural spine,' or the totality of the distinct parts of which such arch is composed. And I am of opinion that the parts of the neural arch which I have called 'neural spine' (spinous process), neurapophysis ('neural arch,' Maclise), together with the basis on which the arch rests, called 'centrum' or 'vertebral body,' are not 'structural varieties,' but the most constant and important elements of the typical segment or vertebra. I have been also led to conclude, with other physiologists, that other laws besides those of 'serial homology' preside over the formation of the animal body. The text of the body of my present work was struck off, with an alteration of the paging and a few corrections immediately after the printing of the "Volume of the Reports" in which it originally appeared, and several months before I received the valuable presentation copy of the work with which Mr. Maclise has favoured me. This must be my excuse to him for not noticing his work in an earlier part of the present one.

* The tendon of the triceps femoris is not ossified in this species, where it passes over the knee-joint at 66′; it resembles in this respect its homotype, the tendon of the biceps brachii, in the fore-limb.

In the horse (fig. 19) the fourth digit is the additional subject of arrested development, and the median one in both fore- and hind-feet, III and *iii*, is the last and sole digit which retains its full and functional development, thus manifesting its character as the most constant and essential of the terminal ramifications of the primitive ray. Rudiments of the metacarpals and metatarsals of the second and fourth digits (*ii* and *iv*, fig. 19) are retained, concealed beneath the skin; these 'splint-bones' of the veterinarian are duly adjusted to serve important uses, and their anchylosis and other abnormal conditions are a common cause of lameness; but the appreciation of their final purpose does not prevent the philosophic anatomist from recognising their real nature and archetypal relations, and thereby the essentially tridactyle character and true affinities of the genus *Equus*.

The carpal and tarsal ossicles undergo corresponding modifications, by confluence or arrested development, concomitant with this progressive simplification of the mammalian hand and foot. And here I am induced to offer a few observations on these bones in addition to the remarks contained in the text (pp. 167, 168).

Much difficulty has been experienced in determining the special homology of the carpal and tarsal bones in the lower vertebrates, more particularly the *Reptilia*, according to the names arbitrarily, in the first instance, applied to them, as they exist in the human skeleton. To gain a clear insight into their nature and relations, it becomes necessary to reverse the usual order of comparison, and to proceed from the lower vertebrates upwards. We first recognise a carpal segment of the fore limb in fishes, where it is represented by a series of short ossicles (fig. 2, 56) intervening between the antibrachial bones (54 and 55) and the elongated rays or fingers (57) of the fin, and usually corresponding in number with the proximal or metacarpal series of those longer rays. When, in the air-breathing vertebrates, the typical number *five* is established, and governs, as a general rule, that of the terminal series of rays or digits, the number of ossicles or short rays at the base of these ought, theoretically, to accord in number with them; and when there are two series of such ossicles, there should be five in each. As regards the second or distal row, this number is actually maintained as a general rule in the order *Chelonia*. The metacarpal bones of the two outer digits are commonly each supported by a distinct carpal ossicle (fig. 12, *u* and *u'*), and these two carpal bones obviously answer to that single one in *Mammalia* (*u*) which supports the metacarpal bones of the fourth and fifth, or two outer digits (IV and V). In large and old turtles (*Chelone*) the same confluence sometimes takes place which converts the two outer bones of the second carpal series into the 'os unciforme' of anthropotomy; and I have seen an instance in *Chelone Mydas* in which the 'os magnum' had also partially coalesced with the 'unciforme.' With regard to the homology of the distal carpal bones, supporting respectively the pollex and index, there can be no difficulty; one is the 'trapezium' (fig. 12, *t*), the other the 'trapezoides' (*ib. z*), and the bone supporting the middle digit, III, is obviously the 'os magnum.' The determinations of the bones of the proximal row is at first sight less easy; we have said that they are theoretically five in number, and we find so many actually in most *Quadrumana*, even in the anthropoid orang*. In this species two of the series (fig. 13, *s*, *s'*) answer to one in the human carpus, namely, the bone called 'scaphoides' (fig. 6, *sc*); that name is accordingly applied to the two inner or radial ossicles of the proximal carpal series in the orang, and they are considered as subdivisions of the 'os

* Zool. Trans. i. 1835, p. 365.

scaphoides'*. The 'lunare' (fig. 12, *l*) is situated on a plane above or proximal of these, and is wedged into the distal interspace between the radius and ulna. The pisiforme (*ib. p*) descends, or is placed more distal, and articulates with both the 'cuneiforme' (*ib. c*) and the outer 'unciforme' (*ib. u*).

In many *Chelonia*, as in *Testudo Elephantopus*, *Testudo græca*, in large individuals of *Chelone mydas*, the two inner or radial ossicles of the proximal carpal series are distinct as in the orang; they obviously, therefore, represent the human 'scaphoid,' and the scaphoid only. Ossification commences in that portion which is nearest the middle of the wrist, or which relates to the 'trapezoides' and index digit in younger *Chelones*: in some *Emydes*, as *Chelodina longicollis*, this is the only portion of the scaphoid which is ossified; in other species again, as *Testudo indica* (at least in old individuals), in *Cistudo clausa* and in *Emys europæa* (fig. 12, *s*), these two portions coalesce, and so form a single scaphoid bone, as in man.

In all *Chelonia* the next bone of the proximal row of the carpus (fig. 12, *l*) holds a higher or more proximal position than the rest, and is more or less wedged into the distal interspace between the radius and ulna; this, therefore, is plainly the homologue of the 'lunare' in the orang (fig. 13, *l*); it is theoretically, and in most *Chelonia* actually, the third bone of the proximal row of the carpus. The next bone towards the outer side which articulates exclusively with the ulna is the 'cuneiforme' (*ib. c*): usually it terminates the proximal series, but sometimes, as in *Cistudo clausa* and *Emys europæa* (fig. 12, *p*), it supports a small 'pisiforme;' and this bone, which is more developed, elongated and compressed in the turtles, articulates, as in the orang, in greater proportion with the 'unciforme' than with the 'cuneiforme.'

In the proximal row of the tarsus in Chelonia, one never finds more than two bones; and sometimes, as in the old *Testudo græca*, these have coalesced into one. The larger of the two, in most *Chelonia* (when they are distinct), articulates proximally with both tibia and fibula, crossing their interspace, and distally with all the bones of the second row except the outermost. It therefore answers to both the 'astragalus' and the 'naviculare' in the human tarsus, and sometimes also, as in the *Testudo græca* above cited, to the 'calcaneum.' The distal series of tarsal bones, like their homotypes in the carpus, are five in number in all Chelonia; the innermost, which supports the metacarpus of the hallux, answers to the 'os cuneiforme internum;' the second to 'o. c. medium;' the third to the 'o. c. externum;' the fourth, which supports the fourth metatarsal, answers to the inner or tibial half of the 'os cuboides;' the fifth, which sustains the fifth digit, to the outer half of the 'os cuboides.'

Thus, in the human carpus, the scaphoid (fig. 6, *sc*) and the unciforme (*u*) are each two connate carpal bones, and they actually manifest this theoretical division in most *Chelonia*. In the human tarsus the os naviculare (69, *s*), the calcaneum (*cl*, *cl'*), and the cuboides (*b*), are each theoretically a compound of two bones; but in the Chelonia the principle of coalescence extends further: there are but two bones in the proximal row; three bones being represented by the larger, and two by the smaller of the proximal tarsals; on the other hand, the five bones of the distal series maintain their normal or typical distinctness.

In the crocodile a single bone of the carpus (fig. 3, *slt*) represents the two divisions of the scaphoid, as well as the lunare, the trapezium and trapezoides; a second bone (*c*) answers to the 'cuneiforme,' and there is a small

* Vrolik, Anatomie Comparée du Chimpansé, fol. 1841.

'pisiforme(*p*);' the bone *u* represents a small 'magnum' and 'unciforme.' In the tarsus, ossification extends from the astragalo-navicular bone *asc*, and takes the place also of the internal and middle cuneiform bones. There is an external cuneiform bone, and a single bone *b* supports the two outer toes, and represents both divisions of the 'cuboides' in the Chelonia. In some Saurians the calcaneum retains its true or theoretical character, the articular portion (fig. 3, *cl*) being distinct from the fulcral or sesamoid portion (*cl'*).

In the dog and other carnivora, and in the wombat, the scaphoid is connate with the lunare; three carpal bones in the wrist of the orang are here therefore represented by one. In the hind-foot of the rhinoceros (fig. 17) the internal cuneiforme is gone, together with the digit it would have supported. In the ruminant the cuboid has coalesced with the navicular (fig. 18, *b s*). In the horse the external cuneiform (fig. 19, *ce*) is the largest of the distal row corresponding with the enormous toe which it supports; and the navicular, *s*, remains distinct from the cuneiform, *b*, which we may suppose to be represented by that portion which in the Emys supports the fourth toe.

In the ruminant the fibula is reduced to a small ossicle (fig. 18, 67), representing its distal end, wedged between the tibia and the calcaneum: the ulna is almost as much reduced in the fore-limb, and is commonly anchylosed to the radius. The two metacarpals of the principal digits, III and IV, coalesce to form the single cannon-bone, and the two corresponding metatarsals are subject to a like coalescence (fig. 18), a single bone supporting the fully developed toes, as in the bird: the rudimental back-toes, *ii* and *v*, have small detached metatarsals when they exist. Whilst the number of toes is thus seen to fall short, progressively, of five, the typical character of that number is still indicated by the power of determining the particular toe or toes of the five in man, which are retained in the tetradactyle, tridactyle, didactyle and monodactyle feet respectively of the lower mammals. But although the number 'five' thus governs the development of digits, properly so called, in all existing air-breathing vertebrata, the tendency to multiplication of terminal rays in the diverging appendages developed for locomotion may be seen to manifest itself in the sexual 'spurs' of the *Gallinacea* and *Monotremes*; in the hereditary supernumerary toes in certain varieties of the common fowl, and even in some individuals of the human race. But the single spur of the tetradactyle cock is not more a homologue of a normal digit in a pentadactyle reptile or mammal, than is the spur of the *Platypus*, or the second spur in the *Pavo bicalcaratus*.

Having thus noticed some of the chief varieties of the mammalian modification of the vertebrate archetype, there remains to add only a few words in explanation of fig. 6,—the diagram of the human skeleton.

As this is that which the anatomist has been accustomed to hear described most frequently and exclusively by the special terms, and according to the special views and ends of anthropotomy, the language in which its deviations from the common archetype have now to be noticed will probably appear strange and bizarre. The comprehension of the explanation will be facilitated by reference to the special name of the bone through its numeral in the column of names whenever such bone is alluded to under its general or archetypal name.

In the first and, notwithstanding the upright posture, the most anterior of the cranial segments, by reason of their forward curvature, the hæmapophysis (21) coalesces early with its own moiety of the divided spine (22), and the same thing happens to the next hæmal arch (20) with subsequent obliteration of the symphysis between the halves of its spine (32).

The pleurapophysis (20) of the first arch remains a distinct bone: its diverging appendage (24) coalesces with and becomes a 'process' of the centrum (5) of the parietal vertebra.

The neurapophyses (14) of the anterior segment are modified as in other mammalia, *i. e.* become confluent together and with the olfactory capsules; but appear externally below the orbital process of the frontal.

The spine (15) is small, but bifid.

That of the second segment (11) attains its maximum of development, as do also the spines of the two following vertebræ (7 and 3). The bifid spine of the parietal segment is truly enormous as compared with that of the fish (fig. 2, 7) or the reptile (fig. 3, 7), in which latter animal the spine, being undivided, adheres closer to the archetype.

The diverging appendage (26, 27) from the hæmapophysis (21) is divided into two pieces, as in most mammals and reptiles; both are broad and flat: the first (26) serves to fix the arch to the parapophysis (12) of the second segment, from which it is here dislocated; the portion (27), which becomes enormously expanded, covers a large vacuity between the third and fourth neural arches, and overlaps by a squamous suture part of the expanded spines of both those vertebræ. It also anchyloses below with the pleurapophysis (28) of the second segment, with the parapophysis (8) and the pleurapophysis (38) of the third segment, as well as with the bony capsule of the organ of hearing (16), forming with those parts the most singularly complex 'cranial bone' of anthropotomy.

The centrums (5, 9) and neurapophyses (6, 10) of the second and third segments coalesce with each other, and with the first pair of diverging appendages (24) of the anterior hæmal arch (20, 21, 22), forming the complex 'sphenoid' bone of anthropotomy.

The centrum (1), neurapophyses (2), and neural spine (3) of the fourth segment speedily anchylose together, and their centrum afterwards coalesces with that (5) of the parietal vertebra, forming the still more complex cranial bone called 'os spheno-occipitale' by Soemmering.

The hæmapophyses of the third much-reduced hæmal arch (40) are ossified only at the extremity which joins the spine (41): the remainder of the hæmapophysis is continued in a ligamentous state to their anchylosed pleurapophyses (38), forming the 'styloid processes of the temporal bone.'

The detached and displaced pleurapophyses (51) of the occipital vertebra attain considerable breadth: their hæmapophyses (52) are ossified only at the extremity which joins the pleurapophysis, and with which it coalesces. The diverging appendage (53–57) here attains its maximum of adaptive development; as in the skate-fish (*Raia*) it exhibits the extreme of vegetative or polaric growth. But the progressive steps by which it departs from the primitive or archetypal simplicity, shown in figures 7 and 8, are so gradual that the special homology of the arm and hand of man with the bifid-jointed appendage of the scapular arch in the amphiuma, and with the simple jointed ray of that of the scapular arch of the lepidosiren, has never been doubted or called in question. In ascending, therefore, to the higher generalization of the signification, or relation to the archetype, of such simple, or bifid, jointed or more complicated appendage of such scapular arch, we are compelled by the truth, as it exists in nature, to admit that the scapular arch in the lepidosiren and other fishes forms the inferior costal or hæmal arch of the occipital segment or vertebra; and, by reference to the archetype, to see in the diverging appendage of such arch, a repetition of similarly simple diverging appendages of succeeding segments. These, indeed, retain their primitive simplicity, as shown in the trunk-vertebræ of the fish (fig. 2, *a a*) and of the bird (fig. 4, *a a*); and that simplicity is very gradually departed from in the case of the appendages of the occipital vertebra, by the stages recognisable in figs. 7 and 8. If, then, it be admitted that the upper limb (arm and hand) of man is the homologue of the fore limb of the amphiume, of the pectoral fin of the fish and of the pectoral ray of the lepidosiren; it follows, that, like the latter, it must also be the 'diverging appendage' of the arch called 'scapular,' which is the hæmal arch of the occipital vertebra; and, therefore, however strange or paradoxical the proposition may sound, that the scapular arch and its appendages, down to the last phalanx of the little finger, are truly and essentially bones of the skull.

The centrum of the first segment of the neck is subject to the same modification as in the ordinary mammalia, the major part (*c a*) remaining anchylosed to the centrum of the succeeding segment (*c d*), of which it forms the 'odontoid process' in human anatomy. The cortical part (*c a, x*) is that which is usually called the 'body' of the atlas: it is connected by aponeurosis to the corresponding part of the centrum of the occipital vertebra: the articulation of the head with the neck is chiefly by means of zygapophyses developed in the form of convex condyles from the neurapophyses (2); and received by the concave zygapophyses of the neural arch of the atlas. In the other cervical segments, the autogenous elements of which they are composed are represented diagrammatically in fig. 6 as distinct, viz. the centrum, neurapophysis, neural spine, and pleurapophysis; the latter element in the seventh vertebra sometimes attains a length nearly equal to that of the first dorsal. In the eleventh dorsal vertebra the elements are additionally indicated by the initial letters. The cervical hæmapophyses (58) are wholly ossified and well-developed. The hæmal arches in the abdominal region retain their aponeurotic texture: the anchylosed and stunted pleurapophyses are continued by the tendinous origins of the 'transversus abdominis;'* the hæmapophyses are the 'inscriptiones tendineæ recti abdominis;' and the basis of the hæmal spines is the 'linea alba.' But these and other modifications of the bones of the trunk have been described at pp. 158–161.

On reviewing the figures in Plate II. it will be seen that the disposition of the whole vertebral column has changed with the progressive modifications of its segments: it soon departs from the geometric simplicity of the archetype, and exchanges the straight line for the curve or a succession of curves.

In the fish the deviation is least: the whole column is straight in some; or it describes but one slight curve, convex dorsal, from the nasal to the caudal vertebræ: some fishes show a slight upward curve of the latter.

In the lower reptiles the whole spine is straight, or simply curved as in fishes: in crocodiles the general curve, extending from the segments of the head along the back of the tail, is interrupted by a slight bend of the neck in the opposite direction.

In the bird, the longer and more slender neck is the seat of an elegant double or sigmoid curve; the segments of the head are directed at right angles to the chord of the cervical curves; and the tail bends upwards in a direction contrary to that of the fixed part of the trunk.

The degree and variety of the curves of the vertebral column vary much in mammalia, according to the medium and mode of their locomotion. In the subject of the diagram (fig. 5), the cranial segments form a slight angle with the cervical ones; and these form another with the dorsal segments: the curve of the back is slightly reversed in the loins, and again resumed in the sacrum and base of the tail; which latter is the seat of extensive and variable degrees of flexuosity, its extremity being spiral and prehensile in

* See Albinus, 'Historia Musculorum,' Tab. XIV. fig. 3.

some quadrupeds. Another mark of adaptive modification may now be seen in the convergence of the spines of the cervical vertebræ towards that of the fourth of this series, and by a more marked convergence of the spines of the dorsal and lumbar vertebræ towards that of the eleventh of the dorsal series: both these points of convergence indicate centres of special motion in these regions of the spine. That in the back commonly relates to the bounding mode of progression of the animal, in which the spine is alternately bent and extended, upon the vertebra with the vertical spine. When the quadruped moves along with a rigid spine by rapid walking or a kind of stiff trot, as in the heavy pachyderms, the spinous processes of the dorsal, lumbar and sacral vertebræ all bend in one direction—slightly backwards—and no centre of motion is indicated by a point of convergence. The elephant and rhinoceros resemble in this respect the stiff-backed crocodile.

In the human frame the succession of slight but graceful curves, and their relation to diffusing shocks and balancing the body in the erect position, have been explained in various estimable physiological works.

In no species do the cranial vertebræ bend at so strong an angle from the chord of the opposite curve of the neck: and in none is the curve of the sacrum and coccyx so strong in proportion to the small number of the vertebræ.

But the most striking characteristic of the human modification of the endoskeleton is the enormous development, both in bulk and special adaptive modification, of the two pairs of diverging appendages retained for the purposes of support, locomotion and prehension. In no mammal does the length of the pelvic appendages, as compared with that of the vertebral column, equal that in man.

Perhaps the greatest obstacle to the contemplation of these members as homologues of the simple diverging rays (*a*, *a*) of the hæmal arch of the typical vertebra, as they are shown in the archetype, and in many segments of the bird and fish, will arise from the early and habitual contemplation of them by the anatomist under their maximum condition of growth and development in its completest sense in man.

In the skate (*Raia*) the pectoral members surpass in relative bulk their homologues in man: but the development of these appendages is of a lower kind: it consists of a vegetative repetition,—division, bifurcation and segmentation—of mere rays, of a multiplication of essentially similar parts, without power of reciprocal action and reaction on one another; all being bound up in one common fold of integument for one simple action—the only one required for an animal so low in the scale, but perfectly provided for by the form of fin in question. At first sight the pectoral fin of the skate with its hundred digits seems a more complex deviation from the primordial single ray, as shown in the lepidosiren (fig. 7), than the pentadactyle upper extremity (53–57) of man; but the complexity is more apparent than real. The high characteristics of the human arm and hand are manifested by the subordination of each part to a harmonious combination of function with another, by the departure of every element of the appendage from the form of the simple ray, and each by a special modification of its own; so that every single bone is distinguishable from another: each digit has its own peculiar character and name, and the 'thumb,' which is the least constant and important of the five divisions of the appendage in the rest of the class, becomes in man the most important element of the terminal segment, and that which makes it a 'hand' properly so called.

In the pelvic, as in the scapular extremity, the same digit (*i*), which is the first to be rejected in the mammalian series, becomes, as it were, 'the chief stone of the corner,' and is termed 'par excellence,' the 'great toe:' and this is more peculiarly characteristic of the genus *Homo* than even its homotype the thumb; for the monkey has a kind of *pollex* on the hand, but no mammal presents that development of the *hallux*, on which the erect posture and gait of man mainly depend.

We perceive, however, that although the first toe (fig. 6, *i*) is the longest as well as the largest, it retains its characteristic inferior number of phalanges; its bulk depending, like the larger toe in the didactyle ostrich, on the superior size instead of an increased number of bones; whilst the fifth or little toe (*v*) still retains with diminished proportions its full complement of phalanges. The teleologist will discern that the requisite strength of the toe, which is the chief fulcrum when the whole body is raised by the power acting on the heel, as in stepping forward, has been regarded in the diminished number of its joints; but the same final cause would not appear to have governed the different number of the equally-sized first and fifth of the five toes inclosed in the massive hoof of the elephant or the webbed hind-paddle of the seal: and whether the hallux be the shortest of the five or the longest, it has always the same number of phalanges whenever it is present, provided it supports a nail, a hoof or a claw, in the mammalian series.

The satisfaction felt by the rightly constituted mind must ever be great in recognising the fitness of parts for their appropriate functions; but when this fitness is gained, as in the great toe of the foot of man and the ostrich, by a structure which at the same time manifests a harmonious concord with a common type, the power of the One Great Cause of all organization is appreciated as fully, perhaps, as it is possible to be by our limited intelligence.

It is interesting to perceive both in the human hand and foot that the digits that have been most modified either by excess or defect of development are precisely those that are the least constant in the mammalian series, the two, for example, that form the extremes of the series; whilst the three intermediate digits are more conformably and equably developed. In the hand, the 'digitus medius'—the most constant of all in the vertebrate series, and most entitled to be viewed as the persistent representative of the terminal segments of the primitive elementary ray,—still shows a slight superiority of size; though few, perhaps, are aware that the bones forming the three joints of this finger answer to those called 'great pastern bone,' 'little pastern bone,' and 'coffin bone' in the horse, and that the nail of this finger represents the hoof in the horse.

In the human foot the three more constant toes, *ii*, *iii*, *iv*, maintain more equality of size than their homotypes in the hand: the middle toe here also is the representative of the chief part of the hind-foot of the horse: but the fourth toe answers to that which, by excess of growth, becomes the chief member of the long and strong hind-foot of the kangaroo. These and the like relations to the vertebrate archetype, which, together with the principle of the fitness of things, govern the forms and proportions of parts of the human frame, cannot but be both interesting and useful to the artist, as being calculated to call his attention to differential characters, which, though constant, may be so slight as to escape attention until their true significance is made known.

The few examples of unmutilated feet from the works of the ancient Greek sculptors show, indeed, how truly their just observation of nature supplied the insight into the archetypal law, and guided them to an exact and beautiful indication of the affinities of the three middle toes as contrasted with the first and fifth, the distinctive characters of the last being as truly given as those of the great toe.

In 'Il Giorno'—the chef-d'œuvre of CORREGGIO at Parma, in some respects the noblest production of modern painting—these characters have been overlooked in the foot of the kneeling Magdalen, in which the toes progressively decrease in equable proportion from the second to the fifth. The same fault may be seen in the right foot of the Mercury in the painting, No. 10, in our National Gallery, attributed to the same great artist, and with which the beautiful right foot of the dead Saviour in the adjoining painting by the more truthful and severe FRANCIA favourably contrasts. Both the Venus and Cupid in the GUIDO of the same Gallery afford examples of the conventional foot, whilst that (the left one) of the Christ in the 'Raising of Lazarus' by Sebastian del Piombo is an example of the beautiful and the true.

To return from this digression to the immediate subject (fig. 6) of the present explanation, besides the 'bones' indicated by the figures and named in the adjoining column, the following are referred to by letters :—in the carpus (56) *sc* is the 'scaphoides,' *l* the 'lunare,' *cu* the 'cuneiforme,' *p* the 'pisiforme,' *t* the 'trapezium,' *z* the 'trapezoides,' *m* the 'magnum,' *u* the 'unciforme :' in the tarsus (68) *s* is the 'scaphoides' or 'naviculare,' *a* the 'astragalus,' *cl* the articular part of the 'calcaneum,' *cl'* 'its fulcral part,' *c i* is the 'cuneiforme internum,' *c m* the 'cuneiforme medium,' *c e* the 'cuneiforme externum.'

In the hand, the bones or segments of the rays immediately supported by the carpus are called 'metacarpals,' the corresponding series in the foot 'metatarsals :' the remaining segments are called 'phalanges ;' those nearest the trunk are 'proximal ;' those furthest from it and supporting the nail 'distal' or 'ungual ;' the intermediate ones are the 'middle phalanges ;' the middle phalanx is absent in the thumb and great toe. It is only in the horse that the phalanges, from their great and peculiar development and frequent disease, have received special names : the hippotomist, in this respect, having done exactly what the anthropotomist had done before in regard to other bones, and for the same good reason. Both, however, will appreciate the necessity of knowing something more of a bone, besides its specialities of form and structure in relation to its uses and diseases, in order fully and truly to understand it. Some knowledge of the archetype, indeed, would seem to be required to enable the anthropotomist to appreciate even the differences of conformation and proportion which must strike his eye in contemplating the immediate object of his descriptions. In the elaborate article on the 'Bones of the Foot,' for example, in the 'Cyclopædia of Anatomy and Physiology' by its accomplished editor, it is stated :—"The toes are numbered from the inner or great toe ; they gradually diminish in length from the first to the fifth :"—"All the metatarsal phalanges possess these general characters : that of the great toe is very considerably thicker than the others, and is slightly longer : the remaining ones differ but little in size," vol. ii. p. 342. Now, besides the difference in degree of diminution observable in the skeleton of well-formed feet, and especially in the races where no artificial compression has been applied to the foot during growth, the proximal phalanx of the little toe is broader and more depressed in proportion to its length ; those of the three middle toes being narrower or more compressed at the middle of their shafts*.

* How little the true nature of the science of comparative anatomy, or anatomy rightly so called, is comprehended, and its indispensable aid to a true understanding of anthropotomy recognised, may be inferred by the definitions of the science of 'Anatomy' in the latest summaries of human knowledge published in this country. Thus in the excellent 'Penny Cyclopædia' we read that "Comparative anatomy includes an account of the structure of all classes of animals *excepting that of man* ; Human anatomy is restricted to an account of the structure of man only," vol. i. p. 198. Art. Anatomy.

In fig. 5. the typical dentition of the placental mammal is shown, viz. that expressed by the formula :—$i\frac{3-3}{3-3}$; $c\frac{1-1}{1-1}$; $p\frac{4-4}{4-4}$; $m\frac{3-3}{3-3} = 44$: which signifies that there are on each side of both jaws three incisors (i, 1, 2, 3), one canine (c), four premolars (p, 1, 2, 3, 4), and three molars (m, 1, 2, 3). The fourth premolar in the upper jaw and the first molar in the lower jaw are called 'sectorial' or 'carnassial' teeth in the carnivora. In the human subject the dentition is :—$i\frac{2-2}{2-2}$; $c\frac{1-1}{1-1}$; $p\frac{2-2}{2-2}$; $m\frac{3-3}{3-3} = 32$; and the absent premolars are the first and second of the typical formula*.

Fig. 7. Hind view of the occipital vertebra of the *Lepidosiren* (*Protopterus*) *annectens* (from nature). The *letters* indicate the bones in their general relation as elements of the primary segment, the *numbers* their special names. All the bones of the fore-limb, from the humerus 53 to the manus 57, are potentially included in the segmented ray *a*.

Fig. 8. Hind view of the occipital vertebra of the *Amphiuma didactylum* (from nature). The general and special names and homologies of the parts are similarly indicated. The articulation of the head to the trunk is already here (in batrachians) transferred, as afterwards again in mammals, from the centrum to the neurapophyses (n 2), and the parts of the neural arch have coalesced together. The hæmal arch is detached from the neural arch, and slightly displaced backwards; but the pleurapophysis (pl, 51) retains its simple rib-like form and position, slightly inclining outwards below from the vertical line. The hæmapophyses (h, 52) do not pass beyond the state of gristle, but are much expanded : they resemble in their histological condition their homotypes, called 'cartilages of the ribs,' in the thorax of man. If the study of the essential nature of the detached inverted arch so formed had been begun at this point and compared with that of the vertebrates lower in the scale, no doubt, I apprehend, would have been entertained as to the detachment of such hæmal arch in the amphiuma being a deviation from type, and its attachment to the rest of its segment in the osseous fishes as being a retention of the typical structure : this condition would have been in point of fact the rule, and the other the exception. In extending the comparison to the higher classes, the instances of the detachment and distance of the scapular arch from the occiput predominate, and its attachment to that neural arch of the skull, in fishes, becomes numerically the exception.

The question then arises, whether the number of instances, or the circumstances under which the instances occur, are to be our guides in judging of adherence to or departure from the archetype. Fishes are the lowest of the classes of vertebrata, and if it be true that to understand the fundamental type of the vertebrate skeleton its study must be commenced, not in the highest species,—not in that skeleton where irrelative repetition is least and adaptive modification most displayed, but in the lowest class, where the reverse conditions prevail,—then the position and connections of the scapular arch in fishes must be regarded as more conformable to the typical structure than the altered position which that arch presents in all the higher classes : and in this conclusion we are supported by observing that the position and relations of the scapular arch in fishes render the cranial segment, of which it there forms part, more conformable with the other segments of the skeleton ; whilst in the crocodile, for example, as explained at pp. 117–119, the occipital segment is unconformable by reason of the absence of its hæmal arch, and can only be made conformable by the restoration of the scapular arch to

* For the determination of the teeth in mammalia, see my 'Odontography,' pp. 514–522.

the place it holds in fishes. For, in fig. 3, with regard to the three segments that precede the occipital one, there are three hæmal arches—maxillary, mandibular and hyoidean; and with regard to the segments which succeed the occipital one as far as the sacrum inclusive, every one has its pleurapophyses if not its entire hæmal arch. The scapulæ, therefore, being what fig. 7 shows them to be, pleurapophyses, the occipital segment in the crocodile is the only one in which those elements are wanting, and the scapulæ are the only pleurapophyses by which the want can be supplied in order to restore the type as it is displayed in nature by the class of fishes.

With respect also to the diverging appendages, *a a*, of the occipito-hæmal arch of the amphiuma, if the anatomist had observed them with a previous knowledge only of the lower class of vertebrata, the bones 54, 55 and 57 would doubtless have been regarded and described only as bifid segments of the primitive simple ray. But the parts having been originally studied from a higher point in the animal series, where the homologues of those segments by virtue of their special developments in adaptation to special functions had obtained special names, those names are naturally and properly transferred to their simplified homologues in the appendage recognized as the anterior limb or extremity of the amphiume: the proximal single segment 53 as 'humerus,' the ossified divisions of the next segment as 54 'radius' and 55 'ulna,' the terminal bifurcation as the 'digits.' This extreme instance of the unity of the plan upon which the limbs of the vertebrate animals have been constructed is a perfectly true one.

Cuvier has most accurately assigned their special names to each of the parts of the fore-limb in the amphiume in his celebrated memoir*. All that I would ask of his most devoted disciple is to reciprocate; to grant the inference as to the signification of the parts arrived at by their study in the ascending route of inquiry, which the homologist is ready to give to the determinations of the special character of the parts which have been obtained by comparisons pursued descensively from man: in other words, to admit that the whole (53–57) in the amphiume (fig. 7) may be the homologue of the ray (53–57) in the lepidosiren (fig. 6); that this may answer to the ray (53–57 *a*) in the fourth segment of the archetype (fig. 1); and that such ray is repeated in the diverging appendages, *a a*, of the succeeding segments of the skeleton: whereby we are led to the recognition of the essential nature of the limbs as developed diverging appendages of the hæmal arches of vertebræ, and the fore-limbs as being such appendages of the occipital vertebra†.

In fig. 9 the elementary condition of the hind-limbs in the vertebrata is shown in nature in a back view of the pelvic vertebra of the *Protopterus* or lepidosiren. The letters signify the general and the figures the special homologies of the parts. The apical elements (63) of the hæmal arch are detached from the basal ones (62) and the rest of the segment, and carry with them the diverging appendages (65–69), as in all other fishes.

Fig. 10 is the corresponding arch and appendages of the *Proteus anguinus*.

* Dans ces deux figures *a* est l'*omoplate*, *b* les plaques sternales cartilagineuses formées probablement des *os coracoïdiens*; *c* l'*humerus*, suivi du *cubitus* et du *radius* qui portent un *carpe* cartilagineux et deux os *metacarpiens* et *phalangiens* osseux. Mémoire lu à l'Académie des Sciences, le 13 Novembre 1826, p. 15.

† The want of connection of a peripheral piece, at its peripheral border, appears to be one condition of its greater extent of variety of form and proportion than in the more central pieces of a natural segment. There is nothing to restrain its luxuriant development from a simple spine to a plate, to a divided plate with intercalations, &c., or to a lengthened segmented ray bifurcating and shooting out into additional segments with indefinite modifications of these.

Here the hæmal arch retains its natural connections with the rest of its vertebra, and henceforth preserves them, with a few exceptions (Enaliosauria and Cetacea), in all the air-breathing classes, up to and including Man. In respect of the modification by displacement, the numerical examples of adhesion to or departure from type are reversed in the pelvic segment, as compared with the occipital one. Mammals, birds and reptiles show the rule, and fishes the exception, typically as well as numerically. There has been, therefore, no difficulty or discrepancy of opinion in regard to the homology of the detached hæmal arch and its appendages in fishes. Cuvier saw in 63, fig. 2, the representative of the 'os innominatum' or 'os du bassin;' and, notwithstanding the degree of displacement to which such rudiment of a pelvis, with its pelvic members, were subject in fishes, Linnæus had as little hesitation in recognizing in the ventral fins the homologues of hind-limbs wherever they were placed. When in their normal position, as at v, fig. 2, they characterized the 'abdominal' fishes; when advanced to beneath the pectoral fins, as at v′, they characterized the 'thoracic' fishes; when still more advanced, as at v″, they characterized the 'jugular' fishes. The species in which the ventral fins were absent were 'apodal,' in the philosophic language of the immortal Swede.

Now all that is here required, in regard to the determination of the locomotive members, is, that no more value be given to the character of detachment and change of place in regard to the scapular arch and its appendages than Linnæus allowed in the case of the pelvic arch and its appendages.

The arms are shifted to and fro in the bodies of the air breathing vertebrates, the legs in those of the water-breathing vertebrates: the arch supporting the arms is fixed in its true place in fishes, and the arch supporting the legs retains its true place in the higher classes; only it is often necessary that it should be so developed as to be applied to many segments besides the one to which it properly belongs. In the proteus (fig. 10), however, the ilium (62) retains its simple primitive rib-like form, just as the scapula does in fig. 8; and it is connected, as we saw likewise in the menopome (p. 159, fig. 28), to its proper vertebra exclusively. The segments of the bifurcated ray in the proteus have been determined by descensive comparison from the higher classes to be, 65, the femur; 66, 67, tibia and fibula; 68, tarsus; 69, metatarsus and phalanges.

Fig. 11. Distal half of anchylosed metatarsus, with the two toes, of the ostrich (*Struthio camelus*), answering to the third and fourth in tetradactyle birds.

Fig. 12. Bones of the fore-foot of a freshwater tortoise (*Emys europæa*): *s* outer division of 'scaphoides,' *s′* inner division of 'scaphoides,' *l* 'lunare,' *c* 'cuneiforme,' *p* 'pisiforme,' *t* 'trapezium,' *z* 'trapezoides,' *m* 'os magnum,' *u*, *u* the two divisions of the 'unciforme:' in this reptile the number of carpal bones is ten, five in each row, corresponding with the number of the digits.

Fig. 13. Bones of the hand of the orang-utan (*Simia satyrus*). The letters indicate the same parts as in the preceding figure. The two unciform bones have coalesced into one, and the number of carpal bones is nine. In the human hand, by the coalescence of the two radial bones of the proximal row to form the 'scaphoid,' it is reduced to eight.

Figure 14. Bones of the hind-foot of the orang-utan: *s*, 'scaphoides,' answering to *s s′* in the carpus; *a* 'astragalus,' answering to *l* in the carpus; *c l* articular part of 'calcaneum,' answering to *c* in the carpus; *c l′* fulcral part of calcaneum, answering to *p* in the carpus; *c i* 'cuneiforme internum,' answering to *t* in the carpus; *c m* 'cuneiforme medium,' answering to *z* in

the carpus; *c e* 'cuneiforme externum,' answering to *m* in the carpus; *b* 'cuboides,' answering to *u* in the carpus, and like it consisting essentially of two connate bones: by a similar connation of two bones in *s*, and also in *cl*, the number of tarsal ossicles is reduced, as in man, to seven.

Fig. 15. Bones of the fore-limb of the wombat (*Phascolomys vombatus*). The letters indicate the same bones as in fig. 12, but the lunare having coalesced with the two connate bones forming the scaphoid, the number of carpals is seven.

Fig. 16. Bones of the hind-limb of the wombat, showing the resemblance to the ulna in its homotype, the fibula 67, by its proximal enlargement, and the superaddition of the sesamoid ossicle 67′, which answers to the olecranon, and becomes anchylosed to the fibula in the monotremes. The olecranon itself is a detached sesamoid in some bats. The hallux is reduced to a small metatarsal (I) and one rudimental phalanx, *i*. The letters signify the same bones as in the tarsus of fig. 14. The foot can be rotated like the hand.

Fig. 17. Bones of the hind-foot of the rhinoceros. The tarsus is reduced by the continued connate condition of *s* and of *cl*, *cl′*, and by the absence of *c i* and of the outer division of *b*, to six bones. The inner toe *i* and the outer toe *v* have disappeared.

Fig. 18. Bones of the hind-foot of the ox. By the connation of *b* with *s*, forming a scapho-cuboid bone, the number of tarsal bones is further reduced to five, and of these the cuneiforme medium is a mere rudiment attached to the back part of *c e*. The functional toes are reduced to two by the rudimental condition of the second *ii* and fifth *v*: the first being wholly absent.

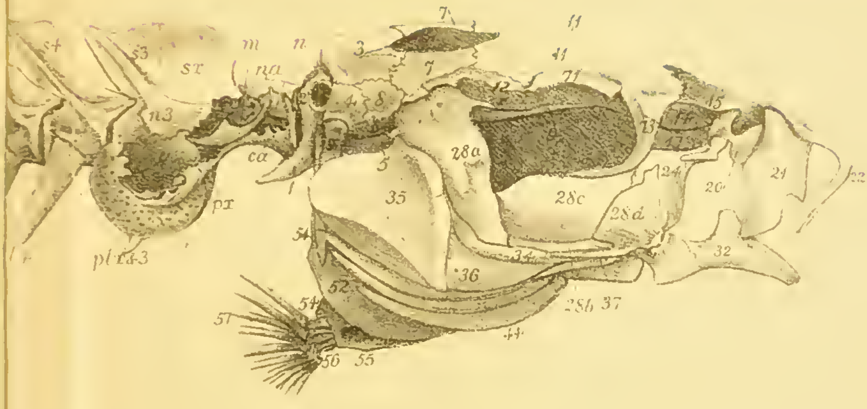
Fig. 19. Bones of the hind-foot of the horse. Here the number of the tarsal bones is the same as in the rhinoceros, but the toes *ii* and *iv* are reduced to mere rudiments of their metatarsal segments, forming the 'splint-bones' of veterinary surgeons. Only the third toe is retained for the functions of the foot, which it almost exclusively represents.

With regard to the order of the descriptions of the cranial vertebræ, pp. 106–139, and of the numbers of the bones in the several figures, it may be asked why I have not begun to enumerate the segments of the head from the most anterior one in the archetypal figure, and the elements of the cranial vertebræ from the centrum of such anterior segment (vomer, 13), and why I did not count all the elements of that segment before going to the next? This order seems so natural, that it may one day be proposed, and perhaps supersede the order of enumeration here adopted. By those, however, who may view the prenasal and other supplementary ossicles in certain fishes and mammals that are anterior to the nasal vertebra, as rudiments of still more anterior vertebræ analogous to those abortive ones at the opposite extreme of the body, the commencement with the vomer as no. 1, would appear equally artificial and arbitrary, as being then regarded the centrum of the 2nd vertebra, or perhaps the 3rd vertebra of the head. It is therefore in order to secure a constant element to commence with, in all vertebrates, that I have begun with the basioccipital. It will be seen by a glance at the typical skeletons in Plate II., that the vertebræ in the middle of the body retain most of their typical character, whilst those at the extremities are subject to most modification: the direction in which the segments are counted must in any case be arbitrary, and in enumerating those of the skull the advantage of commencing with the one that certainly and invariably begins the cranial series determined my choice in counting from the trunk forwards; when if rudiments of segments should be determined anterior to the nasal one, in any animal, they may be reckoned as representing a 5th or 6th cranial vertebra. The order of enumeration of the constituent elements or bones being likewise to a certain extent arbitrary, I have chosen that which appears to me to guide to the most natural course of description of the skull in different animals.

I would entreat the innovator, therefore, to be well assured that he has better grounds than these for changing the order of enumerating the cranial vertebræ and their elements, before he does away with the advantage of having a number as a fixed and determinate symbol of a bone; which advantage would be gained to Anatomy if its cultivators should agree upon a given order of enumeration.

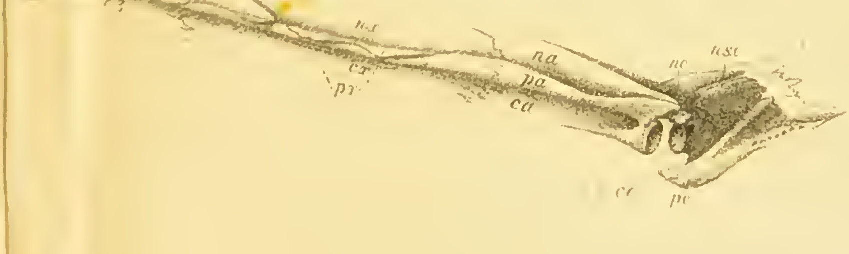
THE END.

PRINTED BY RICHARD AND JOHN E. TAYLOR,
RED LION COURT, FLEET STREET.



53
sr
m
n
na
3
7
8
11
71
12
15
14
13
17
n3
ca
pr
pl
28a
35
28c
28d
24
20
21
32
34
36
52
54
57
56
55
44
37

Fig 6



n3
na
pa
ca
pr
nc
pc

Tight gutters
throughout