Memoirs and memoranada in anatomy / by John Cleland, John Yule Mackay [and] Robert Bruce Young.

Contributors

Cleland, John, 1835-1924.
Mackay, John Yule, 1860-1930.
Young, Robert Bruce.
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Publication/Creation

London ; Edinburgh : Williams and Norgate, 1889.

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MEMOIRS

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MEMORANDA

IN

ANATOMY.

VOL. I.

BY

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MEMORANDA.

I.

ON BIRDS WITH SUPERNUMERARY LEGS, AND ON ABCAUDAL FISSION AND ACEPHALUS; WITH BIOLOGICAL REFLECTIONS.

By Professor Cleland.

PLATES I., II., III.

The occurrence of fowls with one or two appended limbs hanging between the legs on which they support themselves is well known. I had my attention first directed to it by specimens in the Anatomical Museum at Berlin many years ago. I have now four specimens of this abnormality beside me, all differing in detail, and, on comparing them, perceive that they have an interest not hitherto noticed, and that they demonstrate that the cases occurring in the human subject, described as exhibiting an appended undeveloped twin, have been habitually misinterpreted.

The first specimen (Fig. 2) to which I shall direct attention consists of a portion of the skeleton of a pheasant, and belongs to the anatomical collection of the University. It exhibits between the sacrum and the hinder part of the left ilium an angular interval, occupied by a diamond-shaped element, two inches in breadth, and nearly symmetrical, from which hangs an additional limb.

The diamond thus intruded forms one bone traversed transversely, as seen from behind, by the projecting inferior edge of its upper half, which is dorsally convex, while the inferior half, dorsally concave, exhibits, as seen from the ventral aspect, a superior margin thrown into two concavities, with a peak between; and opposite each there is a fossa between the upper and lower halves of the diamond, the right one perforated, the other not. The left of these concave margins lies side by side with a perfectly similar margin continued from the left ischium to the ilium, so as to complete the great sciatic foramen; while the one to the right, abutting against the left side of the sacrum, corresponds symmetrically with the margin completing the great sciatic foramen of the right developed pelvic bone. The upper half of the diamond consists, therefore, of two iliac elements, and the lower consists of two ischial. So much is plain; but the question whether the additional pelvic elements are the right and left of one pelvis or the left of a right pelvis and the right of a left pelvis cannot be determined from this specimen alone.

From the middle of the diamond, under cover of the projecting line on its dorsal aspect, springs a single limb-bone of considerable length, attached by fibrous tissue, and femoral in character in the greater part of its extent, but towards its lower end showing trace of what seems to represent a tibio-femoral articulation. It terminates below in a bent and anchylosed tarso-metatarsal joint, from which a tarsal bone projects forwards to end in processes for three digits, which unfortunately have been lost.

The second specimen (Fig. 1) is a skeleton of a goose, likewise added to the University collection before my appointment. The additional pelvic elements are intruded on the right side of the sacrum, between it and the posterior part of the proper pelvic bone of the right side; but they are so thoroughly united with the proper pelvic bones that it is impossible to distinguish exactly their limits. However, there are two bars united in front and divergent toward the tail, and between these a smaller wedge-like element, pointed in front, and separated there by gaps from the bars between which it lies; and to the dorsum of this wedge at its point is attached a supernumerary limb.

As in the previous specimen, the proximal part of the limb is twisted, but obviously femoral; this is continued into a short and obscure tibial element, and beyond a more distinct anchylosed joint there is a well-developed metatarsal. This metatarsal is continued into three digits. The two lateral digits have each five phalanges traceable, though united by bony union. The intermediate has united to the extremity of its first phalanx two toes side by side, each with three other phalanges. Thus the lateral toes represent a right and left outer toe; and the bifurcated toe represents two third or middle toes, with a first phalanx in common. The dorsum of this composite foot is turned backwards, so that the part corresponding in structure with a left foot is toward the right side of the animal, and *vice-versa*.

The third specimen (Fig. 3) before me is a chicken not many weeks old, which I owe to the kindness of Mr. John M. Campbell. It has a pair of supernumerary legs, well developed, attached by separate joints to the back of a pelvic structure very similar to the diamond-shaped plate of the pheasant already described, but fitting in more loosely between the right side of the sacrum and the right pelvic bone proper. As in that instance, so in this, the supernumerary pelvic structure has its ventral aspect turned to the ventral aspect of the bird; yet the two limbs which come off from it are, the one to the right a left limb, and the one to the left a right limb. As the bones are well developed, although the muscular surroundings are feeble, there is no difficulty in determining this. On examining the viscera of this bird, it is found that, while the intestine is single, there are two pairs of cæca all equally developed (Fig. 6). No other abnormality was observed.

The fourth specimen (Fig. 4) before me was reared by W. J. Shand Harvey, Esq., of Castle Semple, and presented to me through Mr. J. D. Dougall, of Gordon Street. It is a pheasant with a single supernumerary leg, but differs from the specimens already described, first in the pelvic bone of the supernumerary limb being quite disconnected from the pelvic bones proper, and secondly in the presence of two cloacal openings. The pelvic bone of the supernumerary limb may or may not have consisted of representations of bones of opposite sides; but the limb which is anchylosed to it is seen by its toes to belong to the left side. With the exception of the two distal phalanges of the middle one of the three forward toes, its joints are all obliterated; but five phalanges can be counted on the toe to the left, and the toe to the right consists manifestly of three, therefore the limb is a left limb. I observed no trace of the inner or hinder toe.

This pheasant presented the peculiarity additional to the possession of a supernumerary limb, that it had two cloacal apertures, each of about normal appearance, placed side by side (Fig. 5). They opened immediately into a single dilated cavity, and there was only one pair of ureters and kidneys. But it had three cæca, the mesial one in front of the single intestine. This contrasts with the chicken previously described, in as much as the chicken, though possessed of four cæca, could only boast a single cloaca.

It will be observed that in none of the four specimens of birds which I have now described have we had to do with an appended twin. They are all instances of longitudinal fission of the posterior end of the embryo, posterior dichotomy, or what I prefer to call abcaudal fission in contradistinction to abcranial fission; and the developed limbs are in each case the right limb of the right division of the embryo, and the left limb of the left division; while the adjacent halves of the two pelvises, with their respective limbs, have been dwarfed, and in different instances one of them has been suppressed, or the two, unable to get separate, have remained connate in a unity compacted from the blastema of both.

Abcaudal fission is known in the early condition of the chick; and I may illustrate by means of a specimen of a chick of thirty-six hours' hatching, in which two equally-developed vertebral columns diverge from one another behind a single heart (Fig. 7). Both divisions in such a case may continue to develop equally, producing an animal with one head and two bodies. But the peculiarity of all the abnormalities under consideration is that one of the divisions of the vertrebral column disappeared altogether, while the two limbs normally developed belong, one to the division which is preserved and the other to the division which has entirely disappeared.

Instances are known of the development of a supernumerary composite limb in the human subject, on precisely similar principles to those on which such limbs are developed in birds. The best known is the case of Dos Santos, described in this country by Mr. Acton,* by Mr. Ernest Hart,† and by Dr. Handyside.‡ In that case the supernumerary limb had the knee turned backwards, and ended in a composite foot, with the great toes joined and the fifth toes to the sides. It was therefore not the fusion of two limbs belonging to one pelvis, but the fusion of the left limb of a right pelvis with the right limb of a left pelvis. This duplicity, involving the whole lower part of the body, was testified by the presence of two penises lying side by side between the two developed limbs, one for the pubis of each of two separate pelvises. The presence of an osseous element descending in the middle, so as to separate the pubic arch into two was detected by Mr. Hart and Dr. Handyside, and its nature correctly appreciated by Dr. Handyside. Mr. Hart also detected what seemed to have been a second anus which had become obliterated. Both right and left pelvis must have had their right and left walls respectively completed in front; but the adjacent walls of the two pelvises being pressed together by the further development of the

* *London Medico-Chirurgical Transactions*, xxix., p. 103.

† *Lancet*, July 29, 1865.

‡ *Edinburgh Medical Journal*, March, 1866. See also "Ahlfeld Missbildungen des Menschen." p. 98, and Plate XIX.

parts on each side which, on account of their connection with the column above, could not freely separate, obliteration had resulted, leaving a penis and imperfect pubic arch for each pelvis, while the lobes for the adjacent limbs had never been able to separate, but remaining conjoint at their superior or great-toe margins, formed the composite structure which hung from the perinæum.

The case of Blanche Dumas as recited by Ahlfeld (page 89), is almost similar to that of Dos Santos, and seeing that its nature has been appreciated correctly, it is in the last degree surprising that the case of Dos Santos has been so thoroughly blundered.

Once, however, the case of Dos Santos is understood in the light thrown on it by the birds with supernumerary limbs, it follows that on the same principles are to be explained all instances of tumours over the sacrum with bones in them; such as Dr. Richardson's well known case, published by Sir James Simpson,* in which there was what might be called a tibio-femoral bone, imbedded in a ball of adipose tissue, and a single digit overhanging the tumour so formed; the cases figured by Vrolik,† and the numerous cases collected from Authors by Ahlfeld (Plates VII. and XIX.).

The difficulties attending any other explanation are insuperable. If in a partially divided embryo, one division grew more rapidly than the other so that the second, so far as surviving, became an appendage to the first, the place of junction would not be over the sacrum, but either on the ventral surface or within the abdominal cavity. If we adopt the old theory and suppose that embryos on two ova accidentally adhered, a possibility of union of the products of different ova is taken for granted, which really has nothing to support it. But indeed that theory is thoroughly disposed of by Von Baer, who alludes to it as the theory of Haller and Meckel.‡

Thus, I lay down the law that *in cases of supernumerary legs connected with the sacrum or perinæum, the legs developed as the proper legs of the animal belong originally to two different pelvises, being the right limb of a left pelvis and left limb of a right pelvis,*

* *Medical Times and Gazette*, 2nd July, 1859.

† Vrolik, Die Frucht van den Mensch en van Zoogdieren, Tab. C.

‡ While these pages are passing through the press, Professor Virchow, in his Archiv, vol. ciii., p. 426, expresses regret that the number of writers who explain double-monstrosity by secondary agglomeration is again on the increase, and makes valuable strictures on the subject.

and that, in these circumstances the appended limbs may be two, or one of the two may be suppressed, or there may be a composite limb formed by the undivided blastema for two adjacent limbs of two pelvises.

In formulating this statement I am careful to limit it to supernumerary legs connected with the sacrum or perinæum, on account of Von Baer's interesting case of a girl in which two supernumerary legs forming a pair hung over the pubis.* That case rather illustrates what I have said to the effect that in abcaudal fission, the result of one division growing more rapidly than the other would be to bring the place of junction of the blighted or appended parts round to the ventral aspect. In the cases which I have been explaining, the fission has not extended much beyond the site of origin of the pelvic limbs, and the rapid development of the externally situated limb of the aborted division of the embryo has no doubt been effective to unite its pelvic part to the vertebral region above the bifurcation, at so early a date as to crush out of existence its own division of the vertebral column, as well as to dwarf to a greater or less extent the two limbs placed in the middle. But in this case described by Von Baer, the dissection seems to show that the fission extended further, and the explanation of the arrangement of parts is similar to that which I applied years ago to limbs appended to the chest: namely, that, while there was evidence of fission having extended forward as far as the head, one trunk grew more rapidly than the other, and maintained its continuity with the skull, while the less developed trunk became stretched by its connection with the other and so destroyed; its remains being detected in certain cases as a thread going up to the base of the skull.† I suppose that in the case described by Von Baer the fission had not extended so far, but that in similar fashion, the upper portion of the less grown division of the double part of the embryo had been enclosed by the visceral walls of the other, while its lower portion, remaining outside was carried down by the visceral walls, at the expense of stretching and consequent destruction of the enclosed part.

Another instance of unequal development of the two divisions

* Von Baer, Doppelleibige Missgeburten. Trans. Imp. Acad., St. Petersburgh, 1844, p. 79; "Beobachtung IX.," Plates IX. and X.

† *Jour. Anat. and Phys.* May, 1874: "Double Monsters and Development of Tongue."

of an embryo which has undergone abcaudal fission is, to my mind, to be found in cases of completely separate acephalus. This I pointed out, in speaking of the destruction of structure by stretching in instances in which limbs are appended to the chest. I stated that "by far the most probable hypothesis to account for the production of completely separate acephali is that they have become, in process of early growth, detached by fissiparous division from the developed fœtus which always accompanies such a monstrosity. . . . . . An early rupture of the connexion with the head, and with the body of the perfect fœtus, in the case of a completely separate acephalus, would give freedom for growth of the part separated."

That it is difficult, no doubt, to get full proof of this theory, may be frankly admitted. At the same time it may happen any day that an opportunity may occur of examining the body of a healthy twin, born along with an acephalus; and it is possible that, in its internal structure, trace may be found of organs, *e. g.*, lungs, originally belonging to the acephalus. It is easy to understand how, by a very slight change, including the development of an allantois and early rupture of the vitelline duct, the appended limbs of the girl forming the subject of Von Baer's Observation VIII. might have become completely separated and furnished with an independent cord. As for the theory of Claudius—according to which acardiac fœtuses result from the weaker of two originally distinct embryos becoming afterwards united to the other and stronger by anastomoses of allantoic arteries, and consequently having its heart overpowered, the blood stagnating in it, and coagulation and atrophy resulting—it is praised by Förster for its sharp-sightedness, and has been taken up by Ahlfeld,* and is certainly highly ingenious, but is nearly incredible, both in respect of the effect on the embryonic heart imputed to reversed circulation, and in supposing total suppression of large part of the body to result from cutting off of the main channels of vascular supply at an extremely early date, when the formative powers are at their highest. Claudius, it appears, accounts for acormi by the same means. To my thinking, acormi result from abcranial fission, in which one of the two heads so developed is torn, in process of growth, separate from the undivided lower part of the vertebral column.

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* Ahlfeld, Missbildungen des Menschen, page 47.

If anything further requires to be urged against the Claudius theory, it is to be found in the circumstance that it is quite inapplicable to acephalus included within the abdomen of its twin. One case of this sort is recorded and figured by Nathaniel Highmore—"Case of a fœtus found in the abdomen of a young man, London, 1815"—and another is equally elaborately described by G. W. Young, in the Catalogue of Monsters, in the Museum of the College of Surgeons, London, series 1, sub-series 2, specimen 8. In the latter case, found in a boy 10 years old, we are informed that the cyst containing the enclosed acephalus had the pancreas of the containing abdomen stretched over it, a pretty obvious indication that the omphalo-mesenteric vessels of the complete embryo had dragged toward their origin the umbilical vesicle with the other embryo along with it, thereby probably effecting the separation thereof from the common head.

The story, then, of abcaudal fission in which one of the divisions or partially separated embryos outgrows the other seems to be this, that the connection of the parasite, or smaller division, with the vertebral column, is always destroyed by stretching; that the parts not enclosed by the visceral walls of the main embryo are left free to grow; that when the parasite forms external connections by means of an allantois of its own, its union with the main embryo becomes snapped across so as to give rise to a free acephalus, but that when this does not happen it remains appended. When remaining appended, the smaller division or so-called parasite may be attached at different levels mostly in the middle line in front in the sternal region. But I may add here, that to the same class belong those curious cases in which parts of a twin more or less complete escape apparently from the palate, but really from the base of the skull, the connection with the base being stretched by the development of the face.

To all such cases those which have formed the subject of description in these pages stand in broad contrast, because, though they result from a partial duplication by abcaudal fission, the unequal development which has happened in them is not an arrest of the right or left division, but an arrest of the adjacent sides of both divisions so far as the limbs are concerned, combined with disappearance of the right or left series of duplicated vertebræ.

Perhaps it may be well to note in connection with the subject of supernumerary legs that the composite character which they sometimes exhibit is not unknown in the case of the pectoral limbs.

It is well known that, in cases of double-bodied monsters with one head, sometimes a pectoral limb of composite character is found instead of two limbs on the adjacent sides of the bodies; but the only case which I have met with of a composite pectoral limb added to a superficially single thorax, is that described and figured by Tulpius, in which there were two heads, and one trunk, having, in addition to symmetrical arms and legs, a posterior arm ending in two hands with the thumbs adjacent, and a posterior leg similarly ending in a ten-toed foot.*

Bearings on Biological Questions.

The more one looks into the laws of such anomalous formations as we have been considering, the more difficult does it seem to reconcile them with our ordinary notions of individuality. There can be nothing more certain than that the mass of corpuscles destined normally to form a single embryo may, under some abnormal influence, break up into two, each of which inherits all the potentialities of the undivided mass, just as unicellular organisms produced by fission inherit the properties of the parent. The abnormal influence is possibly always external, and as Dareste has shown in the case of chicks, is often a change of temperature. Perhaps that may be the reason why the fission always proceeds from the surface to the deep parts. The fission may be complete, at least so far as the skeleton and parts more superficially developed are concerned, and yet the embryos afterwards become re-united by their adjacent sides joining to make one ventral middle line, and their more distant sides folding round and meeting in like manner to form another ventral middle line; and in this way, as is well known, a composite thorax is formed, or a composite head (janiceps) with two more or less complete faces looking different ways. But in the cases which we have been considering, the fission has never been complete, it has extended from the caudal end forward a greater or less way toward the head.

What I feel disposed to attract special attention to is that in the birds described and in every instance in which a human being is born with a sacral tumour containing vestiges of limbs however indistinct, as well as in a Dos Santos, or Blanche Dumas, there has been at an early date duplicity up as far as the base of the sacrum and including the lower limbs; that this duplicity so far as

* "Nicolaus Tulpius, Observationes Medicæ," Lib. iii, cap. 37. Copied also by Licetus in his work "De Monstris."

it extends is precisely the same thing as the duplicity of the lower limbs of the Siamese twins or any twins born with one set of membranes; and that, therefore, although in such cases the permanent limbs are indeed developed from those free sides of the embryo which would have existed normally, had it not been subjected to fissiparous division, yet it is equally true that they are limbs of two different pelvises, and in that sense not a pair. The sacral tumour may be so small as to be easily amputated, and for all we know, cases may occur in which the supernumerary parts are arrested even before the development of a visible tumour; yet in all of them, the historical peculiarity is the same.

The explanation may be sought in considering that the tendency to fission, possibly never wholly absent from an organism, is only made to show itself by an unusual irritation, and is resisted by all the normal tendencies; and that the influence, whatever it is, which governs the normal growth, may have a certain limited power of recovering the organism from its abnormal condition, by withholding its impulse from certain parts. But even if we suppose this to be the case, we must suppose a certain struggle for existence, in which one of the divisions of the vertebral column is crushed out of being altogether, while as regards the limbs, the advantage remains with the two which have most room to expand.

It may be further pointed out that the occasional more or less fission of the blastema normally destined for one embryo shows the existence of a capability of fission which must be present in every instance, although only in some instances making itself manifest; and each of the masses into which one embryonic mass is capable of dividing must, as it inherits every property, inherit this latent capability also, and so on indefinitely. That this is the case appears to be indicated by the figure given by Ahlfeld* of the tricephalus which was born in Italy, in 1831. For in that drawing a second abcranial fission has taken place in one of the parts into which a first fission has previously divided the cephalic end of the embryo. Also in the remarkable case figured by Ahlfeld † from Fleischmann, there is a parasitic sacral tumour which exhibits, in addition to a left arm and leg, and a finger adherent separately to the right of the tumour, a foot with nine toes evidently not to be accounted for by multiplication of the toes of one foot, but obviously the termination of a composite limb. So that, in this instance,

* Op. cit., Plate XIX. † Op. cit., Plate ~~XX~~, fig. 9.
VII. fig 9.

there have entered into the parasite elements of five limbs. The conclusion apparently justified is a very remarkable one, viz., that *every vertebrate animal has at an early period of its existence a latent capability of splitting up indefinitely.*

If comparison be made of the fissiparous division which takes place in double monstrosity with that which occurs in the nucleated corpuscle, other differences will be found besides the circumstance that in the latter case it is one corpuscle which divides, while in the former it is a mass of corpuscles which does so. Attention has now been drawn for a good many years to the complex changes which occur in nuclei before they divide, and those who cherish the chimerical hope that the phenomena of life will one day be reduced to an evolution founded wholly on the laws of inorganic matter, have not been slow to see in those changes evidence of a total rearrangement of molecules, whereby every minute portion of the nucleus, as it was before the changes set in, is distributed equally to each of the two halves into which the whole divides, so as to secure hereditary transmission of similar properties. It is noteworthy that in the fission which results in twins or double monstrosity, nothing analogous can take place. In this case it is a numerous host of corpuscles which divides, and it is quite impossible to imagine that the members of that host shift their places from one part of the mass to another. It follows that individual corpuscles or groups of corpuscles become, after fission of the mass, ancestors of the textural elements of totally different parts of the body from those which they would have had to do with had the stimulus to fission not been given. It clearly follows that the power by which the different parts and organs of the organism are determined is not resident in the individual corpuscles. For, in that case, the corpuscles destined to give rise normally to mesial structures could not, by any stimulus, become the originators of lateral organs, nor could the laterally situated corpuscles, whose normal destination was to form the groundwork of lateral parts, leave that office and become the sources of crania, vertebral columns, and cerebro-spinal axes. But this is exactly what does take place, when fission of the embryonic shield occurs. Therefore *the factor which models one part into a vertebra, another into a rib, and another into a portion of the sternum is not locked up in the physical properties of the molecules of the separate corpuscles, and there is in an organism, a moulding power additional to the physical properties of the molecules.*

There is abundant other evidence of this, not so satisfactory perhaps to the mere experimentalist as I trust this argument will be, but I shall only refer to one which is specially pertinent to the subject of this paper. Two of the birds described illustrate the law that in fission the alimentary canal is slower to divide than the parts belonging to the somatopleure. But we have in one case a single intestine giving off two pairs of cæca and in another case giving off three cæca. In both cases the intestine is part-property of each of the original divisions of the vertebral column; and in the second case one of the cæca is in the same position. This illustrates that processes coming off from the digestive tube may be multiplied when the tube itself remains single. Still it might be maintained that one half of the digestive tube belonged to each division of the embryo. Such an explanation, however, entirely fails in applicability to double-bodied monsters with one pharynx, two tracheæ, and two pairs of lungs; for as I have elsewhere pointed out,* each trachea in those cases belongs to the vertebral column at the opposite side of the pharynx: therefore the moulding powers of two individualities are at work in areæ overlapping one another.

EXPLANATION OF PLATES.

Fig. 1.—Skeleton of goose with supernumerary composite limb attached to supernumerary pelvic elements on the right of the spinal column. Specimen 2nd.

Fig. 2.—Pelvis of pheasant with supernumerary limb attached to pelvic elements on the left of the spinal column; ventral view. Specimen 1st.

Fig. 3.—Chick with two supernumerary limbs. Specimen 3rd.

Fig. 4.—Supernumerary limb from a pheasant. This limb was unconnected with the rest of the skeleton, and belonged to specimen 4th.

Fig. 5.—Hind part of intestine from specimen 4th, with three cæca and two cloacal openings. Bristles are represented in the orifices the two ureters.

Fig. 6.—Hinder part of intestine of specimen 3rd, with four cæca.

Fig. 7.—Abcaudal fission in a chick of about thirty-six hours' hatching. The fission extends forwards to the back of the first cerebral vesicle. The heart is single.

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* *Jour. Anat. and Phys.*, May, 1874, p. 257.

II.

ON THE FORM OF THE HUMAN SKULL AT DIFFERENT AGES AND IN DIFFERENT NATIONALITIES.

By Professor Cleland.

PLATE IV.

Age.

The skull consists essentially of two parts, cranium and face; and, whether considered zoologically or embryologically, the development of the cranium is earlier than that of the face. Thus, in the oldest vertebrates of which we have certain record, the sharks, which are also the simplest of the craniota, the cranium is largely developed and the face quite rudimentary; while in a chick, during the second day of hatching, the brain is already covered in before there is a trace of the face below it. I allude to these well-known circumstances because they are interesting on account of their bearing on the limitation of the law often laid down on the assumption of genetic relationship, that the earlier a structure appears in the embryo the more remote the ancestry from which it is derived. The late appearance and growth of the face, as compared with the cranium, both zoologically and embryologically, agrees with such a law; while the appearance of the cranium and its contents before the digestive and vascular system can be recognised is in apparent contradiction to it.

The facts of embryology appear to warrant the statement that *the development of both brain and cranium is in the first instance from behind forwards;* while, on the other hand, the trunk is developed vertebra by vertebra in the opposite direction; so that it may be said that a spot, corresponding probably with exactitude to the vital node of Flourens, is the point of departure of two growths opposed in direction like the plumule and radicle of a plant.

But neither the growth of the brain nor that of the cranium progresses regularly from behind forwards. Thus, as regards the brain, the part connected with the eye, namely the primary optic vesicle, is of proportionally enormous size, before there is any discernable appearance of the lateral outgrowth similarly related to the ear, namely, as I maintain, the flocculus; also, the mesencephalon at one period gains a preponderance over the parts both in front and behind, which is afterwards altogether lost, and the cerebral hemispheres, appearing at first in front, expand backwards, so as to cover in man all the parts behind, and bear at birth a greatly larger proportion to the cerebellum than they do afterwards.

Doubtless the irregularity of the rate of development of the different parts of the cranium depends to a considerable extent, though not perhaps altogether, on the peculiar mode of development of the brain. The *curvature of the head* in early embryonic life, known to occur in all the craniota, is obviously the result of the greater development of the brain on its dorsal than on its ventral aspect, while as yet it is a narrrow cylinder, not completely closed on the dorsum. But, notwithstanding that early curve, the base of the skull resumes in the lower vertebrates the original direction of growth, and extends, till arrival at the adult state, in a straight line forwards from the vertebral column. In mammals, however, an added law of growth becomes conspicuous. In them, and even in birds, there is, in consequence of the greater growth of the cerebral hemispheres, an elongation of the roof of the skull as compared with the base, and the cranium becomes thereby curved. This curvature in adult mammals is greater, the greater the enlargement of the hemispheres; until, in man, it completes a semicircle, that is to say—the floor of the forepart of the cranial cavity is parallel, or nearly so, to the foramen magnum; sometimes falling a few degrees short of parallelism, sometimes slightly exceeding it, as I pointed out in my "Inquiry into the Variations of the Human Skull," published in the *Philosophical Transactions* of the Royal Society in 1869. I trust that I now make it sufficiently distinct that this semicircular bend, which I then displayed in its growth and variations, and termed the *cranial curve*, is totally distinct from the embryologists' curve of the brain and its surroundings. The latter, indeed, affects the capsule in which the cranium afterwards appears, but it does not throw into a curve any part of the cartilaginous base. Perhaps this very circumstance is correlated with the splitting up of the cartilaginous base into the trabeculæ.

The extent of cranial curve is not only an element, as we shall see, of importance in estimating differences of race, but is interesting in relation to the changes of form undergone by the skull during growth; and it is in this connection that I now allude to it. It appears, so far as I can judge, to be completed within a few years after birth; but at the date of birth is four or five degrees short of completion, and in skulls, from the fifth to the eighth month of fœtal life, seems on an average to reach little more than 160°. When it is considered that 20° is one-sixth part of the average adult curvature of 180°, it will be understood what a considerable proportion of the length of the adult arch is connected with increase of curvature subsequent to the middle of fœtal life.*

It is to be observed, however, that the great proportional length of the arch, as compared with the base, does not depend solely on the curvature of the skull, but even more obviously on the widening of the cylinder so curved; and a remarkable series of different shapes is passed through in consequence of the different rates according to which arch and base elongate and increase in breadth relatively one to the other.

The arch elongates more rapidly than the base in fœtal life, until at birth or soon afterwards, the arch, as measured from the root of the nose round to the back of the foramen magnum, has reached its highest proportional length, as compared with a straight base-line uniting the same points, namely, a proportion slightly exceeding three to one (Fig. 4). This proportion appears to be retained till somewhere about ten years of age; while *in the adult the proportion is diminished* to a degree varying according to the development of the face bones, and in old age is, I believe, again increased by actual shortening of the base, and sometimes by thickening of parts of the arch. So far as my measurements went, they showed in a set of Scotch skulls an average proportion of 2·72 to 1; in French, 2·67; in German, 2·80; and in Irish skulls, 2·89 to 1.

The breadth of the vault in early childhood also greatly exceeds that of the base; and this, like the comparative elongation of the base just alluded to, is correlated with the growth of the face. At birth the tympanic plate scarcely extends outwards beyond

*My attention has been directed to a paper on the "Sagittale Krümmung des Schädels," by Dr. Lipauer, of Danzig, in the *Archiv für Anthropologie*, vol. xv. Supplement. The writer appears to believe that he is the first to have taken the subject in hand. It is an elaborate paper, full of elaborate Greek nomenclature.

the tympanic membrane; the length of the *external auditory meatus* is a subsequent growth in the first twelve years of life, while up till adult life there is an outward shifting of the lower edge of the *pars squamosa*, connected with broadening of the brain in the region of the middle lobe, and also with continued separation of the condyles of the lower jaw. So also the separation of the external angular processes of the frontal bone means a broadening of the basal part of the anterior lobes of the brain, and separation of the malars with strengthening of the superior maxillaries as well. But as in length, so *in breadth, it is not till birth that the maximum proportion of arch to base is reached.*

The increase in *breadth of the posterior nares* goes on rapidly immediately after birth, before the union of the great alæ with the body of the sphenoid, while the distance between the inner edges of the foramina ovalia does not increase nearly so much. At birth the posterior nares may be about half-an-inch in width, while the foramina ovalia are nearly an inch and a quarter separate; but in the adult the width between the foramina ovalia bears a proportion always a little less than twice the width of the posterior nares, a proportion reached as early as in the second year.

Again, *both in length and breadth, different regions of the vault grow at different rates.* Earlier than the time when the maximum proportion of arch to base is reached, probably about a month before birth, the parietal region has reached a maximum preponderance over the frontal and occipital; and the occipital and frontal regions, but especially the frontal, henceforth grow more rapidly till the adult proportions are reached. In connection with this is the circumstance that about a month before birth the parietal region as seen in profile has the roof more bent on itself from before backwards than afterwards, while the forehead and occipital part of the vault are flatter. After birth, the forehead especially begins to round out at the level of the middle of its height; and the apparent flattening which takes place later in adolescence is connected with the growth forwards of the face and the frontal sinus. It is well known that the degree of separation of the frontal eminences one from the other in the adult is related to the length of time that the frontal suture remains open. Thus, premature closure of that suture is the cause of a triangular form of skull in which the middle of the forehead has been likened to the edge of an axe; while, on the other hand, open frontal suture in the adult, though sometimes found without any alteration of the usual form of the skull, is more frequently associated with abnormal frontal breadth; the continued widening of the frontal region by growth of the brain being in the latter case, as pointed out by Welcker, the cause of the suture remaining open. The occurrence of cases of open frontal suture without increase of frontal breadth does not interfere with the truth of Welcker's observations, but only illustrates that a suture may remain open after the bones have ceased to grow, which is indeed the ordinary rule in other sutures. It is easy, however, to note that the frontal bone widens more rapidly to its permanent width at the coronal suture than it does further forward, and that the most prominent part of the frontal eminences somehow continues to be situated, from birth till adult life, directly above the external angular process, or a shade nearer the middle line; but the extremities of the external angular processes, which are intimately connected with the breadth of the face, continue to retreat one from the other long after the usual period of disappearance of the frontal suture. Indeed, they go on widening the space between them up till puberty, in harmony with the widening of the face. Up to the same or a later date, the frontal eminences continue to rise further above the level of the orbits.

At birth the orbito-nasal angle is greater than it is either before or afterwards. This is another curious instance of different parts growing at different rates in different periods of life. The orbito-nasal angle is an angle of which I first showed the importance in my memoir in 1869. It denotes the angle at which the front of the upper jaw lies to the floor of the anterior fossa basis cranii; and the mode in which I measured it was by taking the angle between a line extending forward from the optic foramen as far as the fronto-nasal suture, and another from that suture to the base of the nasal spine. It is small in early fœtal life on account of the feeble development of the face, while its diminution after birth indicates that whereas the position and size of the alveolar arch at birth are determined by the position of the pterygoid processes and the space required for the young teeth, the enlargement forward required for the full development of the permanent teeth is less than the forward growth of the forehead in connection with the anterior lobes of the brain and the enlargement of the frontal sinuses.

A curious series of changes in the form of the growing skull depends on *each roof bone being at first conical and afterwards* *more nearly approaching a spherical curve.* Before birth it is seen very distinctly that the two frontals, the two parietals, and the supra-occipital each present a prominent eminence whence the bone radiates in nearly straight lines. After birth the five eminences become gradually rounder, while the rounding becomes diffused over a larger part of each bone. But in adolescence there still remains in the mesial plane a comparative prominence between the frontal eminences and another between the parietal eminences, while, below the frontal eminences, and before and behind the parietal eminences, are flat parts which in the male adult are more liable than in the female to be filled up by later development so as to make the antero-posterior curve of the vault more uniform.

The roof becomes more and more flat for some years after birth, but in later adolescence is re-elevated in the mesial plane (Fig. 1). Already at birth the roof is flatter than at an earlier date, and in skulls a few years old the flatness is striking; while throughout adolescence it is greater than in the adult, especially the adult male. The setting in of the flat condition is to be accounted for in part by increase in breadth of base, the operation of which on the parietals is that their lower margins are displaced outwards so as to rotate the bones on their mesial edges. At a later period increase in breadth is, as we have seen, still going on; but it is to a different degree in different instances, and as I formerly pointed out (Op. cit., 148), the period of closure of the frontal suture affects the freedom of increasing breadth even in the parietal region. The consequence, in these circumstances, is that the continued growth at the sagittal suture produces mesial re-elevation, which in the case of the narrow-skulled races may attain to a ridge-like prominence.

Lastly, *the occipital condyles, from infancy to adult life, change their form and alter the position of the skull relatively to the vertebral column.* The changes in question are alike important and easy to understand, yet seem up to the present moment to have completely eluded either the observation or comprehension of anatomists, and this is the reason why I now describe them in more detail than I have already done (Op. cit., 160). At birth the condyles lie flat on the condylar and basilar parts of the occipital and are nearly flat on the surface, but two sets of changes set in with growth. In the first place the articular surface becomes more prominent in the middle, so as to take the form of a ribbon, not only slightly everted in its whole length, but also rather abruptly bent on itself in such a way as to present an anterior and a posterior part separated by an oblique ridge, just as in a dog's or sheep's skull there is a part of the condyle looking downwards, separated by a sharp ridge from the part which looks backwards. These parts correspond to facets on the atlas, and the action of the joint is of a complex description, which need not concern us at present. Suffice it to say, that the flatter condyles of the infant seem less suited for extensive movement than the more curved condyles of the adult. Apparently the movements between the cervical vertebræ become less extensive and the movements between skull and atlas more extensive up till adult life. But in old age the condyles often flatten again, and allow little or no movement.

The other and, I think, more important change in the condyles from infancy to adult life is the growth of a wedge of bone between the forepart of each and the level of the surrounding parts of the skull (Figs. 2 and 3.) This wedge is formed by projection downwards of the lateral angles of the hinder margin of the basilar ossification of the occipital, and plays a most important part in artistic anatomy, although artists, when they sketch without the model, show themselves as ignorant of it as their perfunctory anatomical teachers. It is by these wedges that the position of the head in the erect posture is altered so as to preserve the balance while the head changes its shape. For some time after birth the highest part of the head is placed well back in the parietal region; but as the face and the forepart of the brain get heavier in proportion to the hinder part of the skull, the introduction of these wedges changes the position of the skull, just as in an old-fashioned gun-carriage the direction of the cannon was changed by the introduction of similar wedges. Thus, as adult age is approached, the frontal eminences which projected forwards in childhood are thrown upwards and backwards, and the face and lower part of the forehead in the male owe their adult prominence as much to change of position as to increase in dimensions; while the hinder part of the head, in like manner, is made to appear fuller, not only by real enlargement but by the occipital tuberosity being pulled down.

SEX.

The peculiarities of the female skull consist mostly in the circumstance that some of the later developments which take place in the male do not occur to the same extent. Thus, it was first distinctly pointed out by Huschke that the frontal and occipital capacity are in the female smaller in comparison with the parietal than in the male. The frontal eminences are correctly represented by artists lower and nearer together than in the male, the forehead below them less prominent, and the face bones lighter; while in harmony with these peculiarities the position of the skull on the vertebral column is more childlike, with the parietal region raised high above the forehead, by reason of want of development of the wedges supporting the condyles. Further, there is a general tendency to feeble development of the base both in length and breadth; and in connection with this I would again call attention, as I have done before (Op. cit., p. 130) to the circumstance that the part of the floor of the cranial cavity between the foramen magnum and the anterior fossa basis cranii forms a larger angle with each of these parts than it does in the male, so that, as I express it, the female skull has a more *level base* and the male skull a *steep base*. The difference between a level and a steep base is one which comes out very distinctly in mesial section, and affects the whole conformation of the skull. It is not a difference of importance as a race character, but it is owing to the tendency to level base that female skulls are often so deficient in vertical height. The circumstance that such differences in steepness have no effect in deranging the approach to parallelism of the plane of the foramen magnum and the anterior fossa basis cranii, is surely reason sufficient for including the foramen magnum in the measurement of the base, instead of omitting it, as is done by some measurers who seem unable to understand that a skull is a morphological structure, and not a packing-box. Probably the difference of steepness of base in the two sexes is to be accounted for by a difference in the mode of completion of the cranial curve after birth, elongation of the arch taking place more by frontal growth depressing the base in front in the male, and by growth at the lambdoidal suture opening up the foramino-basilar angle in the female. The cranial curve in the female is probably on an average slightly greater than in the male.

Nationality.

It is not my intention at the present time to enter into an investigation of the detailed peculiarities of the skulls of different races, but only to point attention once again to certain principles which are still too little appreciated. I make no personal complaint. I have to acknowledge, for example, that in Sir William Turner's memoir, in the "Challenger" Reports, every disposition is shown to do justice to anything that I may have done. But facts are stronger than fashions, and when craniologists ignore facts it is a pity for their work.

In my memoir, already referred to, attention was explicitly directed to the mixture of different characters which had long been jumbled together in estimating the prognathous or orthognathous character of a skull, and the considerations there mentioned would have made it plain, had observers taken them into account, that no addition of such words as "opisthognathous" or "mesognathous" could lessen the confusion. Since then, Professor Flower has introduced a new measurement, namely, a comparison of the distance of the basion from the mesial projection of the alveoli with the distance of nasion from basion, claiming for it that it "expresses the measure of *gnathism* of the skull quite as accurately as any of the other methods of angles or indices." It is an improvement on methods prior to 1869; but is a measurement similarly influenced by dissimilar circumstances, and therefore untrustworthy. It is necessary to distinguish, as bearing on gnathous appearances, several distinct matters:—

1. The conformation of the alveolar arch is to be attended to. This determines the *prognathous* or *orthognathous* character of *dentition,* a point which can be most accurately recorded by noting the angle between the floor of the nose and a line drawn down the centre of a first incisor alveolus. Such a measurement would be strictly accurate, and might be accompanied with a record of the angle at which the first upper incisor alveolus lay to the corresponding alveolus of the lower jaw.

2. The relative position of the jaw to the part of the skull beneath which it lies should be noted. That can only be done by measuring the *orbito-nasal angle.* Large size of this angle has nothing whatever to do with prognathous dentition. Prognathous dentition is a thoroughly savage character, and is the most important element in that apparent projection of jaw which Blumenbach and Retzius sought to give importance to. But a large orbito-nasal angle is not a character of savage or degraded sort. The French, and next after them the Scotch, have it large. In the English, I believe, it will be found to be smaller; and in the Irish and the Germans as small as in any nationalities whatever.

3. *Nasal height*, or distance from nasion to nasal spine, is a distinct element, affecting the prognathous appearance of a skull as viewed on a flat table, but neither connected with the dentition nor with the orbito-nasal angle. Compare the elongated face of the North American Indian with a short-faced Negro or Australian with prognathous dentition, and it will at once be seen how absurd it is to confuse two such different characters, because they are accidentally similar in their effects on the appearance as judged by the norma verticalis, or on the gnathic index of Flower.

4. *Measurements of the base* ought to be kept quite distinct from gnathic measurements. But it is obvious that in a skull with a short and level base the gnathic index of Flower will be increased, and that the description of base which will most diminish that index is that which has a steep and elongated clivus, combined with shortness forwards from this to the nasion. The original mode of estimating projection of the jaws by the norma verticalis had the additional fault that it was affected by the amount of the cranial curvature, the increase of which is similar in its effect on the position of the skull when set on a table to what the introduction of a block below the occipital would be.

Cranial curvature should be registered separately, and, so far as my inquiries went, no measurement promised better results. It seemed even to point to a distinction between aboriginal races arrested in development, whose cranial curve was not yet completed, and others, as the Australians, in which it had exceeded the amount found in civilized races. But only those who have access to very large collections can sufficiently investigate such a point.

The use of numbers called indices for the estimation of differences of form in the cranium I consider unfortunate. It always involves a comparison of two measurements which, for all that has been ascertained, stand in no natural relationship one to the other. In the ninth edition of "Quain's Anatomy," Retzius is alleged to have introduced the *cephalic index*, but that great anatomist knew better than to do any such thing, and this I have shown (Op. cit., p. 145). What he really did was to divide skulls into two great groups, which he termed dolichocephalic and brachycephalic on account of length being an important distinction, but by no means the only distinction to be noted between the two groups.

A South German skull, however broad it may be, has no approach to the mesial characters of the brachycephali of Retzius, but it resembles the North German skulls in a great deal. If it be taken into consideration that the mesial base has its parts united by bone at a very much earlier period than that at which the skull ceases to increase in breadth, it will be seen that, according to that generally-accepted law which was referred to at the outset of this paper, the ancestors of the broad-headed races would have had the mesial basal characters of their descendants before they acquired the same breadth. The skulls also of African negroes seem to be worse filled and narrower than those of negroes from America. Altogether, it seems at least highly probable that breadth is a later-acquired character than length, and governed by different laws. I am the more induced to make this remark, when I recollect that in all three regions of the base, viz., foramen magnum, mid base, and frontal base, I found in savage races a greater elongation than in any civilized races. It would seem that *civilization tends to arrest the growth longitudinally of the base, and to induce increase in breadth.* At any rate, it were safer to trust to measurements of absolute length and breadth than to give importance to the proportion borne by one to the other.

With regard to height, which is now recognised as a highly important character, it may be a question whether absolute height, or proportion of height to length is the more important to take into consideration. The disadvantage of the latter is that it is a proportion between two quite distinct things not necessarily connected, and varies according to the rise or fall of either. Still I own that I was induced in 1869 to calculate the proportion of height to length, although I had not the glory of inventing for it the name of "vertical index," "altitudinal index," or "index of height." My reason for making the calculation was that I thought I saw a tendency to height in brachycephalic skulls, and, believing that height was a character less dependent on individual peculiarity than breadth, thought that a means might thus be obtained of accentuating a natural order of brachycephali, such as Retzius aimed at, while, as I suggested, the consideration of breadth would be better made use of for subdividing the brachycephali and dolichocephali, thus gathering the Hindoo, Sandwich Islander, and New Zealander, to which I may add the Burmese and the Malay, under the name of *brachycephali angustiores*, while the South Germans would be distinguished as *dolichocephali latiores.* The circumstance that certain skulls, such as Kafirs and Fijians, combine positive height with elongation, makes the division of skulls into *hypselocephalic* and *tapeinocephalic* inadvisable, although, in an evil moment, I suggested the words, and the same or similar terms have occurred to other writers.

That which ought ever to be considered the most remarkable feature of the brachycephalic order of skulls indicated by Retzius, next to this absolute shortness, is the peculiar curve of the occipital bone behind the foramen magnum turning up rapidly to the probole. In connection with this, however, the circumstance must be taken into account that the occipital protuberance (inion) descends with age, and that most frequently in old age the skull is depressed in a backward and downward direction, the forehead becoming more sloping and lower, while the curve of the arch increases rapidly from before backwards. Thus the appearance in profile is rendered more dolichocephalic even though there may be increased width above the ears (Fig. 4, *c* and *d*.) This shows the importance of taking age into consideration more than it has been in the estimation of racial peculiarities.*

Of the many peculiarities of conformation of the skull, there are some which are manifestly connected with the presence or absence of civilization, and some which are not. To the first of these categories prognathous and orthognathous dentition belong, and also the position of greatest breadth. Malar breadth exceeding the greatest cranial breadth is a distinctly savage trait. Situation of the greatest cranial breadth high up on the parietal bone is likewise peculiar to savages, while in cultivated nations it is placed

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* The greatest care ought to be taken in forming an opinion as to the exact age in the case of skulls which show signs of being beyond the young adult condition. Turner expresses some reliance on the condition of the sutures and the teeth. The uncertainty of the duration of the teeth requires no remark, but even the condition of the sutures is a very far from reliable evidence. Early synostosis is not rare, and I have in my possession the skull of an octogenarian male, whose appearance during life I happened to be familiar with, and it has all the sutures apparently open, with the exception of a slight commencement of closure in the middle of the sagittal. The effects of age set in at a rate greatly varying in different persons. Gravitation changes, and the absorption of diploe in patches are probably signs of age as deserving of attention as any.

near the upper and back part of the squamous suture. Connected with these characters are the roof-shape of skull found in savage races, and the well-filled or rounded-out vertical transverse section found in civilized races. Prognathous dentition, excessive malar breadth, and both the roof-shaped and the well-filled outline are characters which are late in development; and that fact, as well as the circumstance that civilization actually alters the savage characters mentioned, seems to show that all these distinctions must yield in classificatory importance to any which, while characteristic of whole races, are unaffected by civilization. Such a character is the brachycephalic occiput with absolute shortness of antero-posterior diameter; and with regard to height, it may be remarked that, given a required cranial capacity, the brachycephalic occiput is a cause of height. Thus the height-index, or height as well as length, has high classificatory importance, and it becomes clear that while Retzius was right in making the division into orthognathi and prognathi subordinate to that into dolichocephali and brachycephali, it was a pity that he took breadth into consideration at all as a character of the brachycephali, even although he did not fall into the mistake of those who afterwards, and without real appreciation of the sound basis of his classification, made the proportion of breadth a kind of cabalistic charm.

The source of the difference between dolichocephali and brachycephali seems lost in antiquity, even though the two forms mix and graduate one into the other. But one thing seems certain, that no amount of civilization and development of brain will convert a brachycephalic into a dolichocephalic race. On the other hand, if such a skull as that of the Kafir be subjected to the influences of civilization, it may be expected to lose its roof-shape and expand laterally, and as the brain becomes at the same time richer in convolutions, it may be difficult to estimate the future of such a race if it preserves a fine development of the whole body.

EXPLANATION OF PLATE.

1.—Reduced one-half from tracings of transverse sections of three skulls. Each section has passed through the condyles, the forepart of the mastoid processes and the forepart of the parietal eminences:—

- *a.* From a fœtus of the ninth month, preserved in weak spirit, with the brain and integuments unremoved.
- *b.* Skull of about twelve years of age.
- *c.* Elderly adult.

2.—View of right occipital condyle of an infant at birth, as seen on making a mesial section; preserved in spirit:—

a. Basilar process.
b. Part behind the foramen magnum.
c. Inner edge of the condyle.

3.—The same parts in the skull of an adult male:—

a, *b*, *c*. As in preceding figure.
d. The anterior border of the wedge of bone by means of which the skull has been gradually raised up from the forepart of the condyle and tilted backwards.

4.—The mesial curve of the arch of four skulls:—

a. Fœtus four months old.
b. Over two years old—half-size.
c. Adult male.
d. Octogenarian male.

III.

HERMAPHRODITIC MALFORMATION OF THE EXTERNAL GENITAL ORGANS IN THE FEMALE, WITH REMARKS UPON THE SO-CALLED "TRANSVERSE HERMAPHRODITISM."

By John Yule Mackay, M.D.,

Senior Demonstrator of Anatomy.

The appearances about to be detailed were presented by a fœtus of about the eighth month of intra-uterine life, kindly put in my possession by Dr. George Dickson. The special abnormality met with is interesting as belonging to a class of malformations which are but rarely seen, viz., the so-called "transverse hermaphroditism," in which the external organs belong more properly to the male sex, while the internal appertain to the female. But the individual case to be described is peculiarly noteworthy on account of its extreme simplicity as compared with others classified under this heading, and standing, as it does, almost half-way between what is usually described as "spurious hermaphroditism" and those complicated cases in which the external organs are entirely male, it affords a very simple explanation of the latter. So far as I have been able to determine, no case showing a similar arrangement of parts has as yet been reported.

The fœtus is about 14 inches in length. The skin over the whole body is greatly thickened and is thrown into rough folds and wrinkles. The hands and feet are clubbed, and the fingers are reduced in number to four upon the left side, and on the right side to three.

Examination of the external genital organs shows the following arrangement of parts:—a penis slightly over an inch in length and about half-an-inch in diameter, and behind the penis a longitudinal groove or furrow extending backwards to the anus, which opens into its posterior angle. The penis is perforated at its extremity by a longitudinal slit of $\frac{1}{6}$ of an inch in length. The extremity of the organ or glans is slightly thicker than the rest, but is marked off by no fold of skin corresponding to a prepuce. The skin over the whole organ is rough and thick, similar in this respect to the rest of the cutaneous surface of the body. The groove behind the penis is marked by two slightly prominent margins, which on being traced forwards are seen to unite with one another and then to be continued still further forwards, forming the under surface of the penis.

The mesial depression which is contained between these margins possesses in its anterior part a depth of about one-eighth of an inch, and is apparently blind, but further back it shallows to the anus. The whole of the inner aspect of this cloacal depression is lined by mucous membrane, while the lips on their outer surface are covered with skin, continuous with that of the general integument.

The external organs of generation, therefore, present appearances which make it extremely difficult to determine the sex. On the one hand, the presence of a penis of moderate size, furnished at its extremity with a vertical slit, apparently continuous with a canal behind, suggests the male. But, on the other hand, the absence of a scrotum, and the presence in its place of a mesial depression, the walls of which are lined with mucous membrane, throw considerable doubt upon the supposition.

The internal organs are entirely female. The ovaries are small, but distinct, and are contained within the folds of the broad ligaments. The Fallopian tubes are short. The uterus is large and triangular in shape, its walls thickest at the sides, where they are directly continuous with the Fallopian tubes. The cervix is very thick, and opens by a large aperture into the vagina. The vagina, in its upper part at least, forms a large canal, with comparatively strong walls. The whole of the inner surface of cervix and vagina is covered with a mucous membrane of an exceedingly rugose description, the transverse folds being specially marked in the cervix and anterior wall of the vagina.

The bladder is a large thick-walled cavity reaching up the whole way to the umbilicus.

Upon examination, the lower end of the vagina appears at first to end blindly, but, on closer inspection, it is found that it is continued downwards as an exceedingly fine canal for about one-eighth of an inch, and opens into the apex of the median depression before described, situated just behind the root of the penis. Through this small canal a fine bristle may easily be passed, so as to demonstrate the continuity of the vagina with the anterior part of the cloacal aperture.

Turning now to the urinary bladder, it is found that, shortly beneath the entrance of the ureters, a well-marked neck is formed by a dense band of muscular fibres. The aperture of the neck is comparatively a small one, but immediately beyond it the canal of the urethra presents a large dilatation, which extends forwards for nearly one-fourth of an inch. From the anterior extremity of the dilated portion, two distinct canals proceed. The two canals lie in one median vertical plane, the upper one being a male urethra, while the lower opens into a female urinary meatus. They are nearly of similar size at their origin, but as they pass forwards the male passage becomes very much reduced, while the other maintains its size until its termination. Close to its end, however, in the substance of the glans penis, the male urethra again dilates into a very large cavity, similar to that occupying the same position in many monkeys.

The corpora cavernosa are firmly bound to the rami of the pubes, and pass forwards closely united to one another upon the upper surface of a distinct corpus spongiosum. At its anterior extremity the corpus spongiosum forms the glans which, though apparently very large when viewed from the outside, is, upon dissection, seen to consist only of the walls of a large cavity which occupies its substance opening by a vertical slit at the extremity, and receiving the slender urethral canal behind. There is no bulb, but the corpus spongiosum splits behind into two large vascular masses which surround the lower end of the vagina, circumscribing it so closely as almost to occlude it altogether. Between the two lateral parts of the corpus spongiosum a small median portion passes back for some distance, lying between the male urethra and the passage beneath it already described.

The male urethra, taking its origin, as has been already mentioned, from the dilated portion of the common canal, is at first of a size to admit easily a very large bristle. Passing forwards, however, in the substance of the corpus spongiosum, the canal becomes very much reduced, almost indeed to obliteration as a passage, but before it ends in the expanded portion occupying the glans, it is again considerably dilated. The wall of the urethra consisting externally of firm fibrous tissue and internally of mucous membrane, is easily followed. It is so strong that it may be without difficulty separated from the surrounding erectile tissue and entirely dissected out. The mucous membrane is thrown into several longitudinal ridges which are continued forward throughout the whole length of the canal.

The passage to the female meatus courses obliquely downwards and backwards through the anterior wall of the vagina, which it finally pierces immediately above the narrow constricted portion which has been already described. The canal is more than $\frac{1}{8}$th of an inch in length, and posseses strong membranous walls. Its diameter is sufficient to allow the passage of a very large bristle. The other organs are of the normal female type.

Looked at from the developmental point of view, the abnormality admits of a simple explanation. The lateral halves of the corpus spongiosum in the male exist as the bulbi vestibuli and partes intermediæ in the female. The corpora cavernosa remain similar in both sexes, except in respect of comparative size. The lower vascular portions differ, however, very markedly in their subsequent development. They are originally vascular plexuses, lying upon each side of the genito-urinary cloaca. In the male they unite with one another across the middle line forming the bulb, and they are also projected forwards on the under surface of the penis, forming by their median junction the corpus spongiosum and glans. In the female only the extreme anterior ends of these plexuses unite with one another as glans clitoridis, the succeeding portions atrophy, while the most posterior portions remain ununited on either side of the genito-urinary aperture as the bulbi vestibuli and partes intermediæ of Kobelt.

The present case shows an intermediate stage of development, the two vascular masses being partly joined and partly still separate. The anterior ends are united as glans penis, the middle portions, usually atrophied in the female, form here a corpus spongiosum as in the male, while the posterior ends, although separate from one another as in the typical female, are yet brought into such close proximity by the persistence and the junction of the parts in front that they have almost completely shut off from the surface the vaginal portion of the genito-urinary sinus. The anterior portion of the sinus is surrounded and carried forwards as the male urethra, while the posterior portion remains as the nearly obliterated vestibule.

The cases which Simpson* has quoted of "transverse hermaphroditism with the external organs of the male type," and which he has included under the heading of "true hermaphroditism," are very readily explained by comparison with this case. The first,

* Todd's *Encyclopædia of Anatomy and Physiology.* Vol. ii., p. 684.

a case described by Eschricht,* was that of a child. A well-formed male penis was present. The urethra terminated at its extremity and was of the normal male type. There was a scrotum, but it contained no testicle. The anus was imperforate and the rectum opened into the bladder. There was no vagina; but uterus, Fallopian tubes, and ovaries were present; the uterus being firmly bound to the back of the bladder above the spot at which the rectum entered.

The other case of a similar abnormality is described by Bouillaud.† The subject, a person of the name of Valmont, who had been married as a male, presented a penis of medium size. The urethra opened on the under surface of the glans, but was otherwise normal, containing a verumontanum, and being surrounded by a prostate gland. There were, however, no openings of seminal canals. The scrotum was normal but empty. Internally, ovaries, Fallopian tubes, uterus, and vagina were found, the vagina being much constricted towards its lower end and terminating by a small opening in the membranous portion of the urethra.

In both of these cases the abnormal development is of a similar nature to that already described, but it has been carried to a comparatively greater length. The two lateral portions of the corpus spongiosum have united completely, and have thus formed the under-surface of a penis and male urethra. The first case, that of Eschricht, is additionally complicated by an imperforate anus and the disappearance of the vagina following upon the fistulous opening of the rectum into the urinary bladder. In the second case the union of the lateral masses representing the corpus spongiosum has not been quite complete in front, and the urethra opens on the under-surface of the glans.

On the other hand, Simpson *(loc. cit.)* describes, under the heading of "Spurious Hermaphroditism," cases which have evidently arisen from the same process of mal-development—carried, however, to a less extent. Two of these cases of spurious hermaphroditism are interesting in this connection.

The first of these, described by Beclard,‡ was that of a woman in whom the clitoris was enlarged to 10½ inches. The body of this organ was furnished with a canal, the under surface of which was pierced by numerous small apertures. The labia were small, and the aperture between them was blocked by a dense membrane

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* Müller's *Archiv. f. Anat., &c., 1836.*

† *Journal Hebdom. de Med.* Vol. x. ‡ *Bulletins de Faculté, 1815.*

which almost completely closed the cavity, leaving only a small opening. Through this small hole, however, the menstrual fluid and a portion of the urine passed. Urine also escaped by the cribriform apertures in the floor of the canal on the under surface of the clitoris. The other case, reported by Arnaud,* presented a very similar abnormality, but, unfortunately, was not brought to dissection. The clitoris was almost 3 inches long, and showed on its under surface a depression which seemed to underlie the position of a collapsed urethral canal. Towards the posterior end of the organ, however, this canal seemed to be pervious, as it became distended largely during micturition. The orifice from which the urine flowed is said to have occupied its usual position, but the lower end of the vagina was imperforate, and menstruation took place *per rectum.* An opening into the vagina was, however, made by operation, and through this the menstrual fluid afterwards flowed.

In these cases, as in those already described, there has evidently been a junction of the two vascular masses into an imperfect form of corpus spongiosum, so that the case which I have dissected forms a very natural link between them. They all represent merely variations in the extent of abnormal union between two large vascular plexuses. A question now arises as to whether they should be classified under the headings of true or of spurious hermaphroditism. Fortunately the nature of the process renders the answer simple. In true hermaphroditism the genital glands or ducts of opposite sexes are found coexisting in one individual; but in the class of cases under consideration, the malformation is due simply to the abnormal adhesion to one another of vascular masses which are present in both sexes, coupled with a certain amount of hypertrophy. The whole of that class of cases forming what has been called true hermaphroditism of the tranverse type, in which the external genital organs are present of the male formation, while the internal are female, should be relegated to the ranks of spurious hermaphroditism.

* *Dissertation sur les Hermaphrodites*, p. 265.

IV.

GENITO-URINARY MALFORMATIONS CONSEQUENT ON PELVIC DEFORMITIES.

By John Yule Mackay, M.D.

PLATE V.

The varieties of mal-development which have been described in connection with the genito-urinary organs are very numerous, and in many instances the products of abnormal action are so complex that explanation is difficult, often doubtful. The details of the case about to be described, while interesting in themselves and in respect of their apparent causation, are also noteworthy as presenting, when taken together, a marked approach towards the conditions which accompany the more complicated cases of vesical extroversion. It will be seen that the descriptions which follow are in many respects so similar that they suggest at least that the different cases had a similar origin.

The subject is a female fœtus of about the eighth month of intra-uterine development, kindly put in my possession by Dr. Grange of Cumnock. The length of the body from vertex to coccyx is $9\frac{1}{2}$ inches. The upper limbs and upper portion of the trunk are normal, but below the umbilicus many indications of mal-development are met with, the special details of which may be described under the headings of the tissues or systems which they affect.

Bones and Ligaments.

Both feet are clubbed—the right one particularly so. The right tibia shows an intra-uterine fracture, the end of the upper fragment forming a marked projection underneath the skin as may be seen from the plate. The right and left portions of the symphysis pubis are separated from one another to the extent of $1\frac{3}{4}$ inches, and, in consequence of this, the umbilicus is dragged downwards to a position much lower than usual, lying beneath a line drawn between the anterior superior iliac spines. In consequence, also, the lower limbs are widely everted. There is, however, no rupture of the skin. A broad tumour over the sacrum owes its presence to a spina bifida which implicates the sacral vertebræ. An abnormal looseness of the sacro-iliac synchondroses gives rise to a slight backward dislocation of the ilia. The anterior surface of the sacrum is slightly convex forwards. The lumbar part of the column presents a curvature towards the right side.

The effect of these alterations in modifying the capacity of the pelvis is very considerable. In a normal fœtus with a body length of 10½ inches, 1 inch more than the present specimen, the greatest transverse pelvic diameter at the brim was 1⅛ inches, and the antero-posterior measurement from the promontory of the sacrum to the symphysis reached 1½ inches. In the present case, the mesial antero-posterior diameter is reduced to ¼-inch; while the transverse measurement, which is less interfered with, marks under 1 inch.

ANTERIOR ABDOMINAL WALL.

The recti muscles arise from the widely-separated pubic bones, and are consequently very far apart from one another below. As they pass upwards, however, they also reach inwards, and after gaining the level of the umbilicus their internal margins are almost in contact. They are somewhat broader than usual. Strong bundles of fibres pass from each pubic spine to the umbilicus, forming two sides of a triangle, the base of which is represented by fibres of similar strength stretched between the portions of the cleft symphysis. The intervening space is filled up by fibres crossing between these bands, not so dense in character nor so regular in disposition. The middle portion of the anterior abdominal wall below the level of the umbilicus is thus closed in by fibres which extend between the widely divergent portions of the linea alba, and which in the normal state are not represented.

INTESTINE.

The duodenum takes an exceedingly sharp curve, the limbs of which lie in very close proximity. The upper descends from the pylorus and passes to the right side; the lower ascends towards the left to its termination, where, opposite the middle line, it is closely bound to the posterior abdominal wall. Owing to the sharpness of the curve, the pancreas is somewhat dislocated from its usual position, and shows as it crosses a marked convexity downwards. Its duct enters the duodenum separately almost half an inch nearer to the pylorus than the hepatic duct. The jejunum immediately enters the mesentery, the line of attachment of which is directed downwards to the left iliac fossa instead of to the right. There is no part corresponding to the ascending tranverse and descending colon, but the ileum expands suddenly into a wide and irregularly-sacculated tube which passes downwards on the left side into the pelvis, the mesentery merging into a loose meso-rectum.

Examined closely, the tube into which the ileum passes presents four irregular pouches on its attached or mesenteric border. Beyond the last pouch the lumen of the tube becomes considerably reduced, and the intestine leaves the abdomen to enter the pelvis. The pouches possibly represent nothing more than an irregular dilatation of the least resistant part of the tube following upon the atresia of the anus, to be afterwards noticed. But possibly they may be due to the natural tendencies of growth of suppressed portions, the first representing the caput cæcum, and the others portions of the colon. In relation to this question, it is interesting to note the disposition of the blood-vessels. The ileo-colic artery supplies the lower end of the small intestine and the first diverticulum or pouch. The right colic supplies the second and a portion of the third. The remaining portion of the third and a part of the fourth are supplied by the middle colic artery. The inferior mesenteric completes the supply and furnishes branches also to the first part of the rectum. (The letters *b b* in the Plate represent the dilated portion of the intestine.)

It is interesting to note that in spite of the absence of the transverse colon, the great omentum occupies its usual position. Its returning layers are fixed upon the left side to the abdominal wall along the usual line of the meso-colon, and in the middle line to the left surface of the mesentery.

One among a number of otherwise trivial vascular anomalies may be mentioned here—the right hypogastric artery is absent.

GENITO-URINARY ORGANS AND PELVIC VISCERA.

The kidneys are smaller than usual, and their surfaces are smooth and show no lobulation. The right occupies its usual position, but the left is displaced downwards to such an extent that its upper end lies on a level with the lower extremity of its neighbour. The inferior portion of this kidney passes into the pelvis and is much disorganised evidently from the effects of pressure. The right ureter is, at its upper end, normal, arising from the hilus of the kidney and passing downwards on the inner side of the organ, but the left ureter springs from the dorsal surface of the left kidney and courses downwards upon its outer side. A portion of the left ureter also projects further up than the superior extremity of its kidney in the form of a small rounded sac. Both ureters end in a peculiar manner. They pass downwards underneath respectively the right and left horns of a bicornate uterus, and, turning round the outer margins of the horns, become incorporated with their walls on the anterior surface. In the course downwards from the kidney to the uterus the lumen of each is gradually lost so that the tubes are reduced to solid cords before they sink into the uterine substance. The cords may be traced downwards for some distance along the front of the uteri by dissection into the walls. They will be again alluded to in connection with the vaginæ. (The letter *c* in the Plate is placed upon the right kidney, and the ureter stretches between *c* and *d* to end upon the uterine horn.)

Both ovaries are present. Each is about half-an-inch in length. and is rather narrow. It is attached by a fold of peritoneum to the Fallopian tube which lies immediately above it (*e* in the Plate). A firm round ligament connects the ovary with the uterine horn.

Each uterine horn (*d d*) is a tubular structure, containing a long narrow cavity. It is distinguished from the Fallopian tube above, and the vagina below, by its greater thickness. The Fallopian tube, uterus, and vagina upon each side, thus form a continuous tube-like structure, the middle portion of which, the uterus, is thickest, and contains a cavity, the upper portion, or Fallopian tube, thinnest and impervious, while the vagina, intermediate in thickness and somewhat flattened from side to side, is separated from the uterus by a marked construction, and is also impervious. A well-marked round ligament upon each side passes from the upper end of the uterine horn through the abdominal wall in the usual way.

The bladder, the lower ends of the two vaginæ, and the lower end of the rectum, are firmly bound together, and form a compact mass situated in the pelvic cavity. They apparently open externally by a single aperture, the position of which is rather further forwards than that which the vulva occupies in normal circumstances. The opening is less than $\frac{1}{4}$ inch in length, and is surrounded in front and on both sides by prominent folds of skin, which behind merge into the flat margins of a shallow groove, continued backwards between the thighs, to be lost upon the swelling occasioned by the sacral spina bifida.

The anterior wall of the bladder is firmly incorporated with the tissue which has been described as filling up the gap upon the anterior abdominal wall, between the divided portions of the linea alba. The upper portion of the posterior wall is free, but into the lower portion the two vaginæ, which now join with one another, seem to pass directly. To the back of the vaginæ, the rectum is firmly fixed.

When the bladder is laid open by the mesial division of its anterior wall, it is found to contain a cavity which opens widely below. This opening is the entire cloacal aperture before alluded to, which is therefore not subdivided into genital and urinary portions, but passes directly into the bladder. The anterior surface, the fundus, and the upper portion of the posterior surface of the cavity are lined with a whitish membrane, evidently the vesical mucous membrane. This membrane is deficient over the lower portion of the posterior wall, but in front and at the sides it sweeps down to the margin of the cloaca. There is thus left an area in the shape of a horse-shoe upon the base of the bladder, which is left uncovered by the membrane which lines the rest of the interior. Upon examining the uncovered area, it is noticed that it is separated into two portions, an upper and a lower, by an aperture placed between (above and to the left of *f* in the Plate). This aperture is a fistulous communication with the rectum. The portion above it is brownish in colour and soft, the portion below is of a whiter colour and of a firm membranous character, and forms the posterior wall of the cloacal outlet. The impervious vaginæ meet as they reach the back of the bladder. Their more anterior fibres end upon the brown surface above the rectal fistula, while the most posterior fibres descend by the margin of the opening, to form by their junction in the middle line below it the firm whitish area which completes the cloaca behind. The ureters may be traced down upon the anterior vaginal walls for some little distance, but cannot be followed quite to the bladder; their fibres, doubtless, reach the base along with the anterior vaginal fibres just described. The rectum passes down behind the vaginæ where they unite with one another at their lower ends, forming a firm adhesion to their posterior surface, and by means of a perforation extending through the vaginal tissue its cavity is put into communication with the bladder. Still further down the rectum forms an impervious cord which reaches the skin behind the cloaca.

The cloacal outlet represents, therefore, a genito-urinary aperture only, the position of the impervious anus behind it being marked by the blind termination of the gut. The anterior wall of the opening is urinary, being continuous with the anterior wall of the bladder; while the posterior wall is genital, continuous with the vaginal fibres. There is no subdivision into urinary and genital portions. At the same time, the base of the bladder and the posterior urethral wall are wanting, and the anterior vaginal fibres are not prolonged down to the margins of the outlet.

Causation.

Many of the abnormalities present, both in themselves and in their relations to one another, are easily explained. The talipes, intra-uterine fracture, spina bifida, lumbar curvature, looseness of the synchondrosis, with the consequent displacement backwards of the ilia, and separation of the component parts of the symphysis, are all evidences of an interference with the normal development of the bony and ligamentous tissues of the lower part of the body. Inflammations even of a localised and insignificant nature are known, when they occur in early embryonic life, to produce results by their interference with developing structures quite out of keeping with their apparent character. It is exceedingly possible that the same exalted or inflammatory action at a very early period of intra-uterine life, which gave rise to the spina bifida, affecting the sub-cutaneous or sub-peritoneal tissues and setting up irritation, instituted changes in the lower portion of the body, with the effect of disturbing the relations of the bony and ligamentous parts.*

The condition of the anterior abdominal wall—the linea alba being split into two, the gap bridged by fibrous tissues—seems to be referable to rupture, slowly produced, consequent on the separation of the pubic bones. The position of the bladder as it reaches to the umbilicus is one of close apposition to the abdominal wall,

* The manner in which very slight stimulations or irritations may affect the whole development of the body is dwelt on by Professor Cleland, "Contribution to the Study of Spina Bifida," &c. *Journal of Anatomy*, vol. xvii., p. 257.

and in the case of rupture the anterior vesical wall would naturally fill the gap, forming adhesions with the torn edges. In this way the incorporation of the wall of the bladder with the fibrous tissue which crosses the gap receives a simple explanation. It is possible to imagine that, after adhesion in this manner, the causes to which the original rupture was due might still operate with the effect of destroying the anterior wall of the bladder also, and causing its posterior surface to appear upon the abdominal parieties.

The intestines and genito-urinary organs bear traces rather of the arrest of the normal progress of development than of positive abnormal action, and this arrest is in all probability due to the interference with the growth of the containing cavity and to pressure The arrangement of the intestine, the bicornate uterus, the double vaginæ, the small size of the kidneys, and the impervious ureters, are all examples of such a condition. The atresia of the anus is probably due to the pelvic deformity, and to the encroachment of the tumour of the spina bifida. The incorporation of the ureters with the uterine walls is interesting. It is possibly brought about here simply by pressure; but in another case of a fœtus affected with genito-urinary abnormality (in which, however, there was no suspicion of undue pressure) I noticed a connection somewhat similar in character, though of less extent, upon the right side. Boogaard* has described and figured a case in the male in which a persistent Müller's canal was in like manner connected with the coats of a ureter, although their respective cavities did not enter into communication.

The absence of the trigone of the bladder and the posterior wall of the urethra, and the non-development downwards to the outlet of the anterior vaginal fibres, giving to the posterior true vesical wall an appearance of being bifid below, and setting the cavity into wide communication with the cloaca, are possibly also evidences of arrested development. But if this be the case, it is impossible to apply our present notions of the development of these parts to the details of its explanation. Nor, upon the other hand, is it likely that simple fistula could have produced such a complete fusion of the genital and urinary cavities in their lower parts as is here present. The difficulty seems to me to arise from an erroneous conception of the mode of development of the lower part of the bladder—a subject which, however, I shall leave

* Verslagen in mededeelingen der Kon. Akademie van Wetensch-Afdeel. Natuur Kunde, 2e reeks, 9e deel. Also, *Journal d' L'Anatomie* 13.

for consideration until the deformities of a similar nature described in allied cases have been briefly noticed.

Vesical extroversion.

The peculiar feature in this interesting abnormal condition is the appearance of the posterior wall of the bladder upon the front of the abdomen, this being due to a deficiency alike of the anterior abdominal and vesical walls; but in the great majority of cases this malformation does not stand alone, but is accompanied by others of a more or less important character.

The literature of extroversion is exceedingly large. A succinct account of the main details of the deformity is given by Phillips.* And among the many other more recent contributions is one by Champneys† in which the author, after describing a special dissection, reviews very thoroughly the whole subject, and gives an elaborate list of the writers who have already treated it. Still more modern additions to the literature will be found in the description of special cases by Doran‡ and Ogston.§ The general summary which will be given here is in great part drawn from Champneys' paper, and the references to the descriptions cited will be found in the very complete list of works with which that paper is furnished.

The varieties of the characteristic malformation are very numerous. Mayo describes a case in which there was no fissure either of the abdominal or vesical wall, but only a hernial pouch containing a perfect bladder. The pubic bones were five inches apart. Vrolik describes a case in which a perfect bladder protruded through a fissure of the anterior abdominal wall. On the other hand, the posterior wall of the bladder is not only found projecting upon the surface of body, but cases are described in which the vesical surface is partially or completely split into two lateral portions, the intestine or genital organs lying between the parts. Of such a nature are those described by Bartels, Retzius, Friedlander, Rose, Fränckel, Meckel, and Doran. So far as I have been able to determine, in cases of complete fission it is usually only the lower portion of the normal posterior wall which

* Todd's *Cyclopæd. of Anatomy and Physiology*. Vol. i. Article Bladder.
† St. Bartholomew's Hospital *Reports, 1877.*
‡ *Journal of Anatomy and Physiology*, *1881.*
§ *Journal of Anatomy and Physiology*, *1882.*

is present as the divided body, the urinary and generative openings being placed towards the upper extremity of each half. The ureters, when they are not impervious, usually open upon the extroverted surface, in the simpler cases towards the lower end. The vagina, which is very often double, frequently opens immediately beneath it, or between the portions, and even in some very complicated cases upon the vesical surface. The vagina, however, is often quite normal in position.

Champneys' case is very interesting in respect of these openings. The ureters opened separately towards the lower end of the mass, their openings being overhung by prominent wrinkles, suggesting the valvular folds of normal circumstances. Two vaginal openings were placed immediately beneath, overhung in their turn by the projecting lower border of that part of the mass upon which the ureters opened.

The pelvic and abdominal viscera are usually interfered with. The anus often terminates blindly, or there may be fistulous openings into the vagina or upon the anterior abdominal wall, between the lateral parts of the cleft tumour. The ureters are often dilated, sometimes impervious. The kidneys in like manner are frequently affected. The usual arrangement of the intestine is in most cases interfered with, and its peritoneal relations changed. One hypogastric artery is usually atrophied. The penis is frequently split.

There are in almost every case evidences of defects in the bony and ligamentous tissues, particularly those of the pelvis. The symphysis pubis is usually cleft. At one time this was held to be invariable, but sufficient proof has been adduced to show that it is not absolutely constant. Dislocation backwards of the ilia is frequent. Spina bifida is very common; Champneys' and Doran's cases both show examples. It usually affects the sacral or lumbar vertebræ. Curvature of the spinal column is one of the most frequent co-existing deformities. Evidences of similar defects in the bones and ligamentous tissues are usually present in other parts of the body also. Talipes is very frequent, and in connection with the bones of the skull hare-lip and non-closure of the vault have been described.

The theories which have been applied to the explanation of this deformity are exceedingly numerous. Champneys, in his interesting paper, quotes 17 different views, and adds himself one more. It is needless to go into details respecting the many opinions of the different writers upon the subject. The most interesting are those of Duncan, Velpeau, and Isidore G. St. Hillaire. Duncan regards the deformity as due, in the first place, to an imperforate condition of the urethra. Distention of the bladder follows on account of the accumulation of urine, divarication of the pubic bones and rupture of the abdominal and vesical walls follow in sequence, and thus extroversion is produced. It is hardly necessary to refute this theory. The urethra is not found impervious as a rule, nor does the fœtus secrete sufficient urine to distend the bladder to such an extent; and if it did, distension of the bladder is not likely to cause rupture of the abdominal walls.

Velpeau believes it to be due to a process of ulceration from disease, implicating the parieties of the abdomen and bladder. Such a theory does not account for the allied deformities which are so typical of the abnormality. He maintains that the pubic bones are not simply separated but destroyed; but this has not been found to be the case.

Isidore St. Hillaire simply refers it to an arrest of development, and does not attempt to specify the exact manner in which the special anatomical peculiarities are produced. He bases his arguments upon the unmistakable instances of arrested development which invariably accompany the malformation. There is doubtless a general truth in St. Hillaire's theory, but it lacks in detail. Champneys accepts in a general way a theory of arrested development, but seeks to work it out into details, more especially to make it explain the bilateral fission of the extroverted mass which has been noticed as occurring in many cases. According to him the lower abdominal walls have failed to unite from arrest of development. The cleft bladder he explains by regarding the allantois as taking its origin from two lateral portions which subsequently unite to form one vesicle. In this view Champneys follows Bischoff,* who thus assigns a double origin to the urinary bladder.

The explanations offered by Champneys cannot, however, be accepted as satisfactory. The arrest of development is assumed, and no theory of its causation is attempted, nor is anything suggested to explain the very special manner in which the lower abdominal and the vesical walls suffer. In addition, embryologists are now agreed in regarding the allantois as originally a single

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* Entwickelungs-gesch. d. Saugethiere u. d. Menschen, Leipzig, 1842.

structure, and Bischoff's views have not found confirmation in modern research.

Reviewing the details of the undoubted cases of extroversion, and comparing them with those of the dissection which I have described, it will be noticed that the latter approach the former in many respects very closely. The accompanying malformations in my case are those which are found associated with the most exaggerated forms of extrophy. Further, although the abdominal and vesical walls are not ruptured, they yet present appearances from which it is reasonable to infer that the causes which have operated in producing their abnormal condition would, if prolonged or heightened in their action, have resulted in complete cleavage. Finally, had destruction of the anterior wall of the bladder taken place, the posterior wall would have shown, upon the front of the abdomen, a surface bifid below, the rectum opening by a fistula through the vaginal fibres between the lateral portions. I am inclined, therefore, to assign to extroversion a causation similar to that already detailed—interference with the bony and ligamentous portions of the pelvic walls due possibly to early fœtal movements, followiug upon irritation or inflammatory action, and consequent alterations in the shape and dimensions of the cavity.

The mode in which the rupture of the abdominal wall and the destruction of the anterior wall of the bladder take place, has already been sufficiently indicated, and the effect of the interference with the growth of the pelvis in arresting the development of the organs contained in it has been pointed out. Cases are doubtless described in which extroversion was present unaccompanied by cleavage of the symphysis, but it is possible to imagine causes which would produce great lateral stretching, even with intact articulation.

There remains for consideration still, the method by which the apparent fission of the extroverted mass into two portions is produced. From my dissection it is evident that the bifid appearance of the posterior vesical wall is due to the absence of the trigone and the urethral floor, and in extroversion when fission is present the constant position of the genital or anal apertures between the portions, points to a similar condition. The accepted view,* which ascribes to the whole of the bladder and to the first portion of the urethra, an allantoic origin is

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* See *Comparative Embryology.* F. M. Balfour, London, 1881.

unsatisfactory, inasmuch as it does not explain the method by which the ureters are transferred from their original termination on the cloacal end of the gut to the back of the bladder; while the manner in which the urinary and genital ducts are separated from one another at their lower ends is still regarded as an open question.

I am inclined to suggest a hypothesis of the development of the lower end of the bladder somewhat different from the usual one. The cloacal end of the gut is, in a manner not yet accurately known, subdivided into an anterior or genito-urinary portion, and a posterior or intestinal portion, which open separately upon the surface. Into the genito-urinary sinus the allantois ureters and genital ducts open in order from before backwards. Apparently what happens is, that the *tissue between the ureters in front and the genital ducts behind is prolonged down, so as to form a septum, the anterior surface of which persists as the trigone of the bladder and the floor of the first portion of the urethra, while its posterior surface is vaginal.*

Apart from embryological evidence, many things render this probable. Among these are the constant position of the ureters at the upper end of the trigone, the absence of peritoneal cavity between the trigone and the vagina or rectum, and the exceedingly close anatomical connection which subsists between the walls of the lower parts of these organs. Many cases in abnormal anatomy are described, in which ureters or genital ducts opened into cavities other than the usual; and, while some of these are possibly to be explained by fistula, there are others to which that explanation cannot be applied. These can only be understood on the supposition that the septa have developed in an irregular manner.

In my dissection, and in those cases of extroversion in which partial fission is found, the suppression of the septum between the genital and urinary portions, and the consequent absence of the base of the bladder and anterior vaginal wall, explain the bifidity of the lower portion of the vesical wall, and refer it to arrest of development, other instances of which are numerous. Complete fission of an extroverted tumour may be explained on the supposition that the upper portion of the posterior wall of the bladder, as well as the anterior wall, has suffered destruction, the protruded mass representing the lower lateral portions, which, in normal circumstances, bound the sides of the trigone.

DESCRIPTION OF PLATE V

a. Small intestine.

b. Diverticula from large intestine.

c. Right kidney.

d. d. Right and left uterine horns.

Between *c* and *d* the right ureter.

e. Right Fallopian tube.

f. Posterior aspect of bladder.

Above and to the left of *f*, a round aperture indicates a fistulous communication with the rectum.

Above the opening, the limits of the vesical mucous membrane are marked by a horse-shoe shaped edge.

V.

THE ARTERIAL SYSTEM OF THE CHAMÆLEON (CHAMÆLEO VULGARIS).

By John Yule Mackay, M.D.

PLATE VI.

The Arterial System of the Chamæleon (Chamæleo Vulgaris).

Short accounts of the arterial system in the reptilia generally are given in most of the works on Comparative Anatomy, the most detailed being those of Meckel* and Owen.† But even in these nothing more than a description of the larger vessels is attempted. By far the most important contributions to the study of the vascular system in this group are those of Rathke, and his minute descriptions of the vessels which in their origin are more or less connected with the aortic arches have thrown much light upon the development of the larger trunks. In one of his papers‡ he touches upon the arterial system of the chamæleon, but it is chiefly to the aortic roots and to the superficial cervical vessels that he directs his attention. In my descriptions which follow, and which have been taken from the careful dissection of three fully-grown specimens of *Chamæleo vulgaris*, much will be found which differs very widely from the accounts of the typical reptilian arteries, more especially in connection with the vessels of the fore and hind limbs, and of the visceral cavity. A complete account of the many modifications of the vascular system met with in this large group of animals would be a valuable aid to the interpretation of much that is still unsolved in the development of this and allied classes.

The truncus arteriosus arising from the heart, divides into four large branches, the pulmonary arteries and the aortæ. After the division all the trunks arch forwards for some distance

* Traité General D'Anatomie Comparee, J. F. Meckel. Trad. par H. Schuster. Paris, 1837.

† Anatomy of Vertebrates, vol. i.

‡ Untersuchungen über die Aortenwurzeln und die von ihnen ausgehenden Arterien der Saurier. Denkschriften der Mathem. naturwissenchaftlichen Classe der Kaiserlichen Akademie. Wien, xiii Band. 1857.

towards the neck, lying close to one another upon the ventral surface of the trachea. Without leaving the thorax, however, they bend upwards and backwards upon the sides of the windpipe, forming arches, the summits of which are placed on the lateral aspects of that organ. Immediately before the height of the arch is reached, each pulmonary artery is connected with the aorta of its own side by a ductus arteriosus and from this point the vessels begin to separate. Accompanied by the pneumogastric nerves, the pulmonary arteries pass backwards along the sides of the bronchi to the lungs. The aortic arches cross the œsophagus, running obliquely upwards and backwards to reach the middle line and meet one another under the column between the fifth and sixth dorsal vertebræ. The left trunk, which is considerably the smaller, gives off no branches. The right arch gives in succession the left carotid, the right carotid, the right subclavian, the left subclavian, and the arteries of the second, third, and fourth intercostal spaces of both sides. The pneumogastric nerves cross the arches ventrally.

Arteries of the Head and Neck.

The carotids (Fig. 1) are given off very close to one another from the anterior border of the arch very slightly to the right side of the middle line, and, diverging as they proceed, they pass forwards and upwards upon the sides of the trachea for some distance. Leaving the windpipe, they come into contact with the pneumogastric nerve, and are then continued directly forwards in the neck. In this course they are deeply placed, lying dorsally to the muscles which sweep from the hyoid bone to the sternum, and also to the sterno-mastoids. About the middle of the neck a large branch is given off which supplies the tongue, the inferior and lateral parts of the neck, and the shoulder. After this branch is detached the artery is continued almost directly forwards, with a slight inclination upwards, and passes deeply beneath the tympanic bone, and close to the base of the skull terminates by dividing into external and internal carotid trunks.

The common carotid gives but one branch previous to its termination, the *cervico-lingual* (superficial cervical) artery (Fig. 1, *c, l.*), the origin of which has already been commented upon. The distribution of this vessel has been very carefully studied by Rathke, and my dissections agree very closely with his description. Immediately upon its origin it divides into two, one trunk passing forwards and inwards on the neck, the other running outwards and backwards towards the shoulder. The anterior division, or *lingual* artery, passing forwards and inwards, escapes from the cover of the sterno-mastoid muscle, and reaching the upper surface of the group of muscles which stretch between the inferior maxillary and hyoid bones, is continued forwards along the upper surface of the base of the tongue towards the extremity of that organ. During this course numerous branches are given off as follows:—(1) A set directed backwards and upwards in the neck, one of the branches sinking deeply, to terminate by inosculating with the ascending cervical branch of the subclavian; (2) branches directed inwards to the trachea and œsophagus, the most anterior of these reaching as far forwards as the back of the palate; (3) twigs ramifying among the muscles which pass between the hyoid bone and the lower jaw, approaching in this area a set of branches from the external carotid artery; (4) terminal divisions in the substance of the tongue. The other portion of the superficial cervical trunk may be named the *scapular*. This artery courses backwards, upwards, and outwards towards the shoulder, crossing underneath the pneumogastric nerve and the great vein of the neck. Close to the shoulder it gives off a branch which ramifies underneath the deltoid muscle, and may be called suprascapular. The main trunk then reaches the inner surface of the shoulder girdle, and breaks up into a number of small twigs. A posterior scapular branch runs backwards above the shoulder blade; a sternal branch sweeps forwards along the inner surface of the coracoid bone, and a twig runs inwards along the brachial nerves to anastomose with a slender branch coming outwards from the ascending cervical of the subclavian. These divisions are all very minute, and approach very closely the main trunk of the subclavian artery which here crosses over the first rib.

External Carotid.—From the termination of the common carotid artery the external carotid courses upwards and backwards along the posterior margin of the skull, slightly overlapped by the projecting edge, the convexity of the curve thus made being directed forwards. Reaching the under surface of the temporal bone, the artery passes through a foramen and gains the side of the skull, where it divides into its terminal branches, the occipital and temporo-facial. By means of its branches this artery supplies almost the whole of the outer aspect of the head and also the dorsal muscles of the neck.

Branches of the External Carotid.—(1.) The *submental*, a very slender branch, is directed towards the angle of the jaw, on the inner surface of which it ramifies, running forwards for a short distance, giving slender branches upon both sides. Some of these latter approach very closely the more anterior twigs of the cervico-lingual artery.

(2.) The *inferior maxillary*, a large branch, after leaving the parent trunk, passes to the inner surface of the tympanic bone, along which it descends; reaching, however, the inferior maxillary bone, it changes its direction, and courses along the inner surface of that bone towards the mouth, lying in this portion of its course in a deep groove upon the inner aspect of the bone. About half way forwards the groove conducts the vessel to the inferior margin of the bone, and the artery turns round this to gain the outer aspect, upon which it is still continued forwards towards the middle line. Internal to the tympanic bone two muscular branches are given which are directed forwards. At the posterior extremity of the lower jaw an inferior dental branch is detached and enters the bone. The terminal twigs of the artery ramify upon the under lip, forming part of a circle of anastomosing vessels which surrounds the oral aperture.

(3.) The *transverse facial* is a very slender trunk which runs forwards towards the angle of the mouth, and is soon lost in muscular twigs.

(4.) While the artery is passing through its bony foramen a minute branch is detached, which enters the substance of the bone.

(5.) The *occipital artery*, one of the terminal divisions into which the parent trunk splits, takes its origin upon the outer aspect of the skull, close to the foramen. It passes forwards on the under surface of the projecting portion of the skull to reach the occipital bone. Changing its direction it bends backwards among the dorsal muscles of the neck, and breaks up among them into a large number of branches. The twigs which this vessel gives origin to in its course are all of very minute size, and supply skin and muscles.

(6.) The *temporo-facial*, the largest of all the branches, passes forwards through the temporal muscle to the back of the orbit, there to terminate in two divisions, which enter the posterior portion of a large plexus of vessels surrounding the base of the eyeball. In the course forwards over the lateral part of the skull the branches are not numerous; they extend from both sides of the vessel into the muscle, and reach the skin. A few reach the outer extremity of the circumoral anastomosis. The orbital plexus will be described after the internal carotid artery.

Internal Carotid.—The internal carotid trunk, very much smaller than the external, bends from its origin forwards and inwards to reach the base of the skull, where it enters a deep bony groove in which it continues its forward course for some distance. At the anterior end of the groove the vessel divides into two, one portion passing upwards through a foramen to reach the base of the brain, the other bending forwards and outwards to join a branch of some size which passes backwards towards it from the orbital plexus. During its course the internal carotid artery supplies upon both sides two or three minute branches, which ramify upon the base of the skull. Upon the brain the artery distributes a large number of branches, some of which pass backwards in the direction of the spinal cord.

Orbital Plexus.

The orbital plexus is a large collection of arterial vessels which completely surrounds the eyeball, the thickest portion being behind where the terminal divisions of the temporo-facial artery enter it. The plexus receives its blood from them alone, but distributes it to surrounding parts by a number of different channels. One set of efferent branches is directed forwards, and the trunks comprehended in it may be named from their destinations superior labial, superior maxillary, external nasal, and supra-orbital. Branches pass backwards for a short distance on the optic nerve. The largest branch, derived from the orbital plexus, however, is the one which joins the internal carotid artery. This trunk courses downwards, inwards, and backwards, to form the inosculation, giving off secondary twigs from both sides, which are distributed upon the base of the skull. Those which run forward may be divided into anterior palatine and internal nasal trunks, while those which take a backward direction, of less importance, supply the lateral aspects of the cranial base. The junction with the internal carotid is formed after that vessel has given off its cerebral branch and is of a direct character. The connection of the internal carotid artery with the large reservoir of the plexus must have an important influence in maintaining the even constancy of the cerebral circulation. If more blood were being carried by the internal carotid arteries than was required for the brain, the excess would more readily pass towards the plexus than through the narrow foramen leading into the cranium. On the other hand, if the supply from the internal carotid artery were deficient, blood from the plexus could easily find its way to the brain. In other words, the size of the foramen limits the supply of blood which can go to the brain, while the elasticity of the walls of the rete mirabile maintains the supply so long as the constituent vessels are at all distended.

Arteries of the Fore Limbs.

The *subclavian arteries* (Fig. 2), arise in close proximity to one another from the right aortic root. The vessel of the right side passes forwards at once into the space between the first and second ribs, but the other trunk crosses the vertebral column to gain a corresponding position upon the left side. Between the ribs both vessels continue outwards for a short distance, crossing the space obliquely forwards, and finally turn over the borders of the first ribs in company with the lower brachial nerves to become axillary. In this course the arteries are placed dorsal to the pneumogastric nerves, and in their first parts at least are to be compared to intercostal vessels.

Branches of the Subclavian Artery.—The first branch of the left subclavian artery belongs to the right side of the body; and will be described after the others. The second branch of the left vessel may be called *ascending cervical.* It arises very close to the commencement of the parent trunk and passes forwards in the neck, running in the line between the muscles underneath the vertebral bodies and those below the transverse processes. Near the base of the skull it turns upwards and terminates by anastomosis with a branch of the cervico-lingual artery already described. Its branches are numerous. The first, a very slender trunk, passes outwards along the nerves of the brachial plexus, and partly supplies the first intercostal space, partly ends in anastomosis with the scapular branch of the cervico-lingual. A set of branches are next given off, the first of which arises in close proximity to the one just described. These vessels pass towards the spinal canal, which they enter between the transverse processes, the most posterior twig passing between the second and third dorsal vertebræ. Before entering they detach very slender branches outwards along the nerves, and afterwards they are continued on to the ventral aspect of the spinal cord, on which they principally ramify. Very small anastomosing offsets were with difficulty and imperfectly traced, stretching between those small vessels, forwards and backwards, by the sides of the vertebral bodies, after the manner of a vertebral artery. Another set of branches arise from the ascending cervical artery and pass inwards on the under surface of the column, chiefly to supply muscles. Finally, from the outer aspect of the vessel branches take their origin, the distribution of which is similar to that of the terminal twig already alluded to. They end among the dorsal muscles of the neck, in close proximity to branches of the occipital artery.

The *internal mammary* and *internal thoracic* arteries are the next branches of the left subclavian. Both of those vessels take their origin close to the end of the subclavian artery immediately before it becomes axillary. The internal mammary passes backwards by the side of the sternum, and can be traced across four or five intercostal spaces. Very small lateral branches are derived from it and enter the spaces, but owing to the extremely minute size of the vessels the usual anastomoses with intercostals was not seen. The internal thoracic artery, a very slender trunk, could be traced backwards across two or three spaces about the line of junction of the ventral and middle thirds of the ribs. The branches of the right subclavian are similar to those of the left, which have just been described, with the exception that the branch of the ascending cervical which supplies the muscles underneath the vertebral bodies is derived from the vessel of the opposite side.

The *axillary artery* furnishes two sets of branches ramifying respectively upon the anterior and posterior borders of the hollow. In connection with the anterior vessel some circumflex branches arise which course round the upper end of the humerus.

The *brachial artery* passes down the limb running along the inner side of the biceps muscle to reach the elbow. The branches which are derived from this vessel are very slender, they hold mostly a downward course among the muscles toward the joint.

In the hollow of the elbow the artery, still continuing its straight course through the limb, sinks deeply between the bones of the forearm to reach the extensor aspect down which it passes. The main trunk of the lower portion of the fore limb may therefore be termed *posterior interosseous.* This artery is placed at its lower end very deeply, lying between muscles which correspond to the pronator quadratus and extensores breves pollicis of human anatomy.

The branches are numerous and important. Near the upper end a *medio-ulnar* artery is first given off. This arises from the posterior border of the parent vessel and bends ulnarwards and downwards through the flexor aspect of the limb. Close to its origin small recurrent branches are given; these course backwards towards the joint. Further down the artery divides into two sets of branches. The first, median, running straight down the limb along with the flexor tendons towards the palm, passes underneath the ligament which bends the tendons down, but cannot be traced distinctly into the hand. The second, ulnar, runs along the ulnar border of the limb in the direction of the fifth digit, and lies between the anterior and posterior annular ligaments. It also is of very small size.

The second branch which the posterior interosseous artery furnishes may be called *radial.* It springs from the anterior border of the main trunk and passes almost straight down the limb along the anterior margin of the radius. At its lower end it may be traced to the root of the radial digit in the space between the anterior and posterior annular ligaments. Some branches approach the vessels upon the dorsal surface of the carpus, which are derived from the posterior interosseous, but they cannot be traced into actual anastomosis. Other branches are derived from the posterior interosseous upon the extensor aspect of the limb, but they are small and entirely muscular.

Upon the back of the carpus opposite to the deep cleft which divides the three inner from the two outer digits, the main artery divides into two branches, from which are derived the vessels which supply the fore-foot. Each of the two branches subdivides into two interosseous vessels, and these are continued forwards between the bones to divide again beyond the web into lateral digital trunks. From the interosseous vessels branches are given after the manner of perforating arteries, which sink down between the bones into the palmar aspect. The vessels of the manus are therefore entirely placed upon the dorsal aspect.

AORTA.

After the union of the right and left roots already described, the aorta is continued backwards underneath the vertebral bodies. Opposite the body of the third vertebra beyond that which bears the last diminutive rib, and immediately in front of that which articulates with the ilia, it splits into three divisions. The central of these is the continuation of the aorta backwards underneath the sacral and caudal vertebræ. The two lateral may be named common iliac arteries. The branches which the aorta furnishes during its course backwards are parietal and visceral.

The *parietal branches* are intercostal and lumbar, and as these vessels, though numerous, are essentially alike in all the main features of their distribution one description will suffice for them all. The first intercostal of either side is derived from the ascending cervical branch of the subclavian artery; it is a very minute vessel. The second, third, and fourth spring separately from the sides of the right aortic root. The succeeding vessels arise in order from the right and left sides of the aorta. Immediately upon their origin the arteries sink between the bodies of the vertebræ and the long muscles which stretch backwards upon their lateral margins. Further outwards they lie in the substance of the intercostal muscles, and they may be traced for a considerable distance between the ribs. In the dorsal portion of each space they course obliquely forwards towards the posterior border of the anterior rib. Their branches are of the usual description. A dorso-spinal passes upwards between the necks of the ribs, an anastomatic stretches forwards above the rib-neck, while collateral branches ramify in the intercostal space. Among the collateral series one is interesting in respect of its course; it passes forwards above the body of the anterior rib to be distributed in the space in front of that to which its parent trunk belongs.

The *visceral* arteries (Fig. 3) are of an exceedingly simple character. From the right root and from the aorta a number of slender straight vessels pass directly to the œsophagus, where they freely ramify, and send on branches, which, on reaching its ventral aspect, pass along the pleuro-peritoneal folds to the pericardium and lungs. Behind the œsophageal branches, three intestinal arteries arise in close proximity to one another. Their place of origin from the aortic stem is opposite the lower end of the stomach, and so close are they to one another here that they are occasionally reduced in number by the confluence of their bases. The distribution of the three separate branches is very peculiar. The trunk intermediate at its origin is, in its distribution, the most anterior of the three. This artery courses through the meso-gastrium downwards and forwards to the dorsal edge of the stomach, along which it is distributed, its fine branches reaching the ventral edge of the viscus and passing forwards towards the œsophageal arteries, and backwards towards the pylorus to anastomose there with another vessel. The vessel the most posterior of the three at its origin, passes directly downwards through the mesentery to supply the median portion of the small intestine, its branches being intercalated upon the tube between the anterior and posterior divisions of the artery next to be described. The last vessel, most anterior at its origin from the aorta, is the largest. This trunk divides into two portions, the anterior of which supplies the pyloric end of the stomach and the duodenal portion of the small intestine, and gives branches which accompany the bile duct through the mesogastrium towards the liver. The posterior division reaches the tube in the neighbourhood of the cæcum, which it supplies with branches. Its terminal twigs reach backwards upon the large intestine nearly to the cloaca. No other intestinal branch arises from the aorta. One or two branches stretch out towards the reproductive glands, and still further back an artery passes on each side to the kidney.

The caudal continuation of the aorta, though comparatively a slender trunk, maintains its size almost to the extremity of the tail. In its course under the caudal vertebræ, it occupies an imperfect canal formed by processes. Its branches are very slender and of the nature of intercostal or intervertebral trunks.

The *common iliac* arteries are short trunks measuring each about one-fourth of an inch in length. They give off no branches, but divide at their terminations into external and internal iliac vessels. The *external iliac*, much the smaller of the two, passes inwards with an inclination backwards along the junction of the abdominal and pelvic walls, and divides into branches as it proceeds. The branches are very slender, and appear to ramify in the abdominal wall after the manner of epigastrics. Some minute twigs seem to be prolonged towards the thigh, but they could not be followed.

The *internal iliac* trunk passes down into the pelvis, running along the lateral wall in company with the sacral and sciatic nerves; and breaks up into a large number of branches. These are visceral and parietal. Two twigs ramify upon the upper portion of the cloaca, and a third sweeps backwards for some little distance to end upon the skin on the margin of the aperture. Of the parietal arteries one has a course similar to that of the human obturator vessel in its intra-pelvic portion, and another corresponds to a lateral sacral trunk. The continuation of the internal iliac passes into the thigh in company with the large nerves, as a sciatic trunk.

Arteries of the Hind Limb.

The *sciatic artery* in the thigh lies deeply between the back of the femur and the hamstring muscles, and is continued straight down into the popliteal space. Its branches are small and numerous, and pass in all directions among the muscles, the greater number of them having a direction forwards, inwards, and downwards. A special branch, larger than any of the others, and accompanied by a large branch of nerve, leaves the main artery close to its upper end and passes forwards and inwards across the posterior aspect of the bone.

The *popliteal trunk* courses straight down through the space, to divide below into anterior and posterior tibial vessels. In its course two branches of some size are furnished. The first of these, muscular in its distribution, passes downwards, running along the margin of the tibia towards the inner side of the ankle, where it is lost among the muscles at the base of the innermost toe. Its terminal branches appear to communicate with the tibial extremity of the dorsal arch. The second branch of the popliteal trunk is articular in its character. It arises as a single vessel which divides into two, the branches circling the bone above the joint and distributing twigs to the interior.

Anterior Tibial Artery.—Of the terminal divisions of the popliteal artery, the anterior tibial is by far the larger. This vessel passes through between the tibia and peroneal bone, and occupies a position in the upper third of the leg close to the anterior surface. As it passes downwards, however, the artery sinks more deeply, and in the lower third the vessel is found between the two bones, lying in front of a muscle corresponding to the pronator quadratus of the anterior limb, and behind a short extensor of the inner toe. Traced still further, the vessel courses behind a strong interosseous ligament, which binds the lower extremities of the bones together in front, and finally it escapes from the cover of this to reach the dorsal surface of the tarsus, upon which it divides. Muscular branches are derived at intervals from the artery during its course. Near the lower end of the vessel two somewhat larger trunks pass towards the outer and inner borders of the anklejoint. The largest branch, however, is the posterior communicating, a trunk which is given off immediately above the square pronator muscle. Coursing from this position downwards and backwards, the communicating vessel reaches the posterior aspect of the leg close above the ankle joint, where it receives the termination of the posterior tibial artery. After the junction has been effected, the vessel divides into an outer and inner portion, the distribution of which will be followed under the description of the posterior tibial trunk.

The terminal divisions of the anterior tibial artery upon the dorsal surface of the tarsus may be named the *internal* and *external tarsal* arteries. Each of these trunks furnishes two interosseous vessels, which pass onwards between the metatarsal bones to divide at the cleft of the toes into lateral digital arteries. From each interosseous trunk two large perforating branches spring and pass downwards into the plantar aspect of the foot. The extremities of the external and internal tarsal vessels are turned back towards the leg as slender trunks, which pass upwards as if for anastomosis, but the fine branches of these and neighbouring arteries are so small that they cannot be traced into direct continuity.

The *posterior tibial* artery, a long slender trunk, passes down the back of the leg between the superficial and deep muscles. Some muscular branches are given off after which the calibre of the trunk, now much reduced, is restored by the inosculation with the large posterior communicating branch of the anterior tibial artery. Above the ankle joint the vessel breaks up into two branches. The inner of the two branches runs downwards towards the inner side of the joint and approaches closely to the terminations of the long tibial branch of the popliteal artery and the internal tarsal artery. The outer of the two trunks, into which the posterior tibial divides, is traced towards the outer side of the ankle in the direction of the termination of the external tarsal artery; but direct communication was not successfully made out. In its course a minute twig is detached which appears to supply the articulation of the ankle.

No vessels were found coursing along the outer and inner borders of the foot, nor were any seen to enter the plantar aspect from the leg. Here, as in the hand, the vessels of the extremity are placed upon the dorsal surface, the plantar being supplied by perforating branches which sink between the metatarsal bones.

DESCRIPTION OF PLATE VI.

THE ARTERIAL SYSTEM OF CHAMÆLEO VULGARIS, SCHEMES.

FIG. 1.—ARTERIES OF THE NECK AND THORAX.

T. a. Truncus arteriosus.
R. a. r. Right aortic root.
L. a. r. Left aortic root.
C. a. Carotid arch.
L. c. a. Left carotid arch.
C. Carotid artery; *C. e.*, external carotid; *C. i.*, internal carotid.
C. l. Cervico-lingual artery; *Sc.*, scapular branch; *l.*, lingual; *h.*, hyoid.
S. r. Right subclavian artery; *S. l.*, left subclavian.
In. Intercostal arteries.
Ao. Aorta.

FIG. 2.—ARTERIES OF FORE LIMBS.

S. Left subclavian.
As. c. Ascending cervical branch.
I. m. Internal mammary.
I. t. Internal thoracic.
Br. Brachial.
P. i. Posterior interosseous.
M. u. Medio-ulnar.
R. Radial.
D. c. Dorso-carpal.

FIG. 3.—ARTERIES OF INTESTINE.

Ao. Abdominal aorta.
1. Stomach.
2. Bill duct.
3. Small intestine.
4. Large intestine.

VI.

THE ARTERIES OF THE HEAD AND NECK AND THE RETE MIRABILE OF THE PORPOISE

(PHOCŒNA COMMUNIS).

BY JOHN YULE MACKAY, M.D.

PLATE VII.

CETACEAN animals, as a group, present many peculiarities of general structure, the effects of which, as modifying the vascular system, are exceedingly interesting to study. The rudimentary state of development of the limbs and the extreme shortness of the neck have a large influence in altering the usual arrangement of the vessels of the parts which they most affect. In addition, the anatomy of the great arterial rete, possessed by many of them in connection apparently with their power of remaining underneath the water for considerable periods, has lately become the subject of controversy. The descriptions in this paper are taken from the dissection of two specimens (adult and fœtal) of the common porpoise, which were put at my disposal through the kindness of Professor Cleland. Short accounts of the anatomy of the larger arteries and of the rete mirabile in the cetacean class are given by Hunter,* and by Owen,† but only a general summary is attempted by either. I need only touch briefly upon those points which have already been sufficiently described.

The first of the primary branches of the aorta, a large innominate artery, divides into two, the brachio-carotid and an artery which Owen, guided by the nomenclature of human anatomy, calls the posterior thoracic, but which is found in the anterior portion of the thorax, coursing backwards as far as the fifth rib. The second of the primary trunks is the left brachio-carotid. The third vessel

* "Observations on the Structure and Economy of Whales." John Hunter, *Philos. Trans.*, 1787.

† Anatomy of Vertebrates, Vol. III., page 546.

arising from the aortic arch is a comparatively slender trunk which distributes branches to the left side of the œsophagus and to the cervical portion of the left rete. This vessel is not mentioned by Owen in his general description. The last trunk which the aortic arch supplies springs from the descending portion at a considerable distance from any of the others. It is the left posterior thoracic.

The *brachio-carotid* arteries, very short trunks, pass forwards and outwards, to terminate by dividing into subclavians which pass outwards, and common carotids which stretch forwards. It is of great importance to notice that the pneumogastric nerves, which in most mammals cross ventral to the subclavian arteries, are placed dorsal to these vessels in the porpoise. The nerve of the left side passes ventral to the arch of the aorta, and sends its recurrent branch forwards upon its dorsal surface, and upon the right side the posterior thoracic artery has relations to the nerve, similar to those of the aorta upon the left. The explanation of this seems to be that the posterior thoracic is the artery corresponding to the usual mammalian subclavian, while the subclavian artery of the porpoise represents the subclavian found in birds, crocodiles, and chelonians, crossing ventral to the pneumogastric nerve, and considered by Sabatier* different from the ordinary subclavian of mammals. It is interesting under these circumstances to note the branches which the two stems, subclavian and posterior thoracic, in the porpoise, give off, in as much as they are both the representatives of vessels which supply the anterior limbs. The distribution of the carotid arteries may, however, first be shortly described.

The *common carotid*, after an exceedingly short course, divides into the external and internal trunks. In the adult specimen the common carotid, though exceedingly short, is still appreciable, but in the fœtus the vessel hardly can be said to be present, and the brachio-cephalic trunk divides at its extremity into three arteries, the subclavian, the external carotid, and the internal carotid. No lateral branches arise from the common carotid stem.

The *external carotid* artery holds a straight course forwards and upwards through the neck from its origin to the posterior border of the ramus of the lower jaw. Then bending directly forwards it passes internal to the ramus and is continued towards the

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* Observations sur le transformations du Systéme Aortique dans la Série de Vertébrés. Annal. d. Sc. Nat., 5 Sér., Tom XIX.

under surface of the eyeball. It is better, however, to consider the continuation of the vessel which dips deeply internal to the ramus as a branch, under the name of internal maxillary artery, and to describe as external carotid only that portion of the trunk which intervenes between the origin and the posterior edge of the ramus. The branches of the vessel are numerous. The first to come off upon the right side takes upon the left side its origin, not from the external carotid but from the subclavian. It may be called superficial thyroid. This is a vessel which passes forwards and inwards upon the ventral aspect of the neck close to the skin to be distributed to the trachea and larynx, and to the cutaneous structures underneath. Its most anterior branches stretch forwards for a short distance in front of the hyoid bone. The superficial thyroid artery of the left side, although differing in origin from, is in its distribution quite similar to its neighbour of the right side. The other branches of the external carotid vessels are symmetrical. The next branch may be called superior thyroid, it passes inwards to the parts around the hyoid bone as a very slender trunk. The lingual artery follows. This vessel is of considerable size and courses forwards among the muscles of the tongue to reach the under surface of that organ. A large submaxillary branch runs inwards behind the lower jaw. The last branch which the artery gives before passing into the internal maxillary may be called occipital. This, a very slender vessel, is directed backwards upon the skull and breaks up there into a great number of very minute branches which anastomose with the branches of a much larger occipital trunk derived from the subclavian artery.

The *internal maxillary* trunk, the continuation forwards of the external carotid, is at first deeply placed internal to the ramus of the lower jaw, and is directed thence almost straight forwards to the anterior and outer part of the floor of the orbit. The branches are important. The inferior dental artery leaves the parent trunk under the cover of the ramus, enters a dental canal, and, after coursing through the substance of the bone, escapes near the symphysis by a mental foramen. After the dental artery has been furnished, some muscular branches are given off; these are small and supply the muscles on the deep aspect of the ramus. At the posterior angle of the orbit a temporal artery arises. This rather a small branch, courses upwards upon the skull behind the the eye and divides into many straight branches which ramify over the vertex, anastomosing with the occipital of the sub-clavian behind and with the supra-orbital in front. Underneath the globe of the eye the internal maxillary artery supplies a number of branches which divide upon the orbital muscles and anastomose with twigs coming forwards from an ophthalmic vessel. These may be styled orbital branches. A supra-orbital artery is next given off. This vessel courses upwards along the inner wall of the orbit to a foramen upon the upper border, through which it passes to gain the roof of the skull, where it anastomoses with branches of the temporal behind and the infraorbital in front. From the lower edge of the internal maxillary vessel, while it is still beneath the eyeball, nasal and palatine branches pass off. These vessels, of medium size, descend with an inclination forwards through bony foramina to supply the mucous membrane of the cavities of the nose and palate. A superior dental artery is also furnished to the upper jaw.

After all these branches have been given off the internal maxillary artery is continued forwards as an infraorbital trunk. This vessel passes through a bony foramen on the anterior and under aspect of the orbit, and divides on the fore part of the face into a large number of branches which may be distinguished as labial, facial, and external nasal.

The *internal carotid* artery, in its course through the neck and method of entry into the skull, is similar to the corresponding trunk in the mammalia generally. Its branches are distributed within the cerebro-spinal cavity, but, owing to the absence of the vertebral trunks, their arrangement differs from that which is typically met with. Immediately upon reaching the cranium meningeal branches are detached. These sweep in all directions over the dura mater and are distinguised as anterior, middle, and posterior groups. The posterior set anastomose with a large number of small branches which enter at the foramen magnum, and stretch forwards for some distance upon the basilar portion of the occipital bone. These vessels are derived from the spinal rete. After the meningeal vessels have been given off, a slender ophthalmic artery is continued forwards upon the optic nerve to anastomose in the orbit with orbital branches of the internal maxillary artery.

The arteries which supply the brain are anterior, middle, and posterior cerebrals, and in their distribution upon the surface of the brain they are exactly similar to the corresponding vessels of human anatomy. The posterior cerebral artery, however, is entirely derived from the internal carotid trunk. In addition, as this vessel sweeps backwards it detaches branches which supply the cerebellum and medulla, and it likewise furnishes an important branch which, piercing the dura mater close to the foramen magnum, enters the canal of the spinal column between the membranes and the bone. Here this branch runs backwards as far as the anterior dorsal region where it is lost. In the course it is deeply placed in the substance of the spinal rete, with which it very freely communicates. By means of this trunk the vessels of the brain are placed in direct communication with the great arterial reservoir which occupies the thorax and extends into the spinal canal.

The *subclavian* artery is at its origin nearly equal in diameter to the external carotid trunk, but rapidly diminishes owing to the number and size of the vessels which it distributes. The artery of the left side gives off as its first branch the superficial thyroid vessel which has already been described. The second branch upon the left and the first upon the right, is a large and important trunk and may be named cervico-occipital. This trunk, arising from the anterior border of the subclavian, runs forwards and outwards for a short distance and then divides into two vessels. The posterior of these supplies the superficial parts of the lateral region of the neck in front of and above the fore limbs. The anterior branch, of much larger size, courses forwards and upwards until it approaches the back of the skull. Then it turns upwards and backwards and terminates among the dorsal muscles in anastomosis with a large dorsal branch derived from the posterior thoracic. As it is bending backwards behind the skull, it furnishes a large branch which passes directly forwards over the surface of the occipital bone and breaks up into many twigs which anastomose with the occipital and temporal of the external carotid.

From the posterior border of the subclavian the phrenic artery springs. This is a large trunk which rapidly divides into two, an internal mammary portion running backwards upon the ventral wall of the thorax, and a larger phrenic division accompanying the nerve through the cavity. Further out the subclavian furnishes a number of very minute branches, which pass from both sides of the vessel forwards and backwards for a short distance, and supply muscular and cutaneous structures upon the ventral aspect of the neck and thorax. Still further out, now very much reduced in size, the subclavian divides into brachial and external thoracic branches. The brachial divides into two, which, again dividing, form a number of long slender trunks which run down the fore-limb, supplying it completely. There is therefore to be met with in the limb, not one, but many arterial trunks having a downward course upon it. The external thoracic artery turns backwards upon the lateral wall of the thorax, and breaks up, giving rise to a number of branches.

The small vessel which arises from the arch of the aorta, next in sequence to the left brachio-carotid stem, is represented upon the right side by a branch from the posterior thoracic artery. It may be named *deep thyroid* artery. The vessel runs forwards and inwards for a short distance, sinking dorsalwards as it goes, and breaks up into branches which pass in all different directions. Certain pass inwards, towards the œsophagus upon which they bend backwards for some distance, running upon its outer coat; others pass directly backwards, along with the pneumogastric nerve, and seem to end by supplying the sheaths of vessels and nerves at the anterior outlet of the thorax. Finally, lateral branches stretch outwards in the neck, after the manner of intercostal trunks, giving twigs to the cervical portion of the rete, and piercing into the dorso-lateral muscles.

Posterior Thoracic Arteries.—The difference in the mode of origin of these vessels has been already pointed out, and the presence of a branch from the right trunk, which upon the left side is represented by a vessel from the arch of the aorta, has been noticed. It remains to describe the points which are common to both. They arch forward upon the dorsal wall of the thorax, then crossing the rete they pass outwards, and finally they bend backwards over four intercostal spaces which they supply. The line of their course is along the outer margin of the rete, at the junction of the ventral three-fourths with the dorsal fourth of the costal wall. The branches which they give are of three kinds. The intercostal arteries of the first four spaces sweep round the wall of the thorax to anastomose with the internal mammary below. They are slender vessels. The dorso-cervical or deep cervical trunk, a large branch, is similar in its distribution to the dorsal branch of an intercostal artery. It passes between the neck of the first rib and that of the second to reach the back, and is then continued forwards among the dorsal muscles almost to the base of the skull, giving branches freely upon its way. At its termination it forms a small rete at the back of the skull, into which enter branches from the subclavian and from the small vessel which springs from the aortic arch upon the left side, and from the first part of the posterior thoracic trunk upon the right. The last set of branches which the posterior thoracic supplies are exceedingly numerous and of small size. They enter the arterial rete.

A comparison of the branches of the posterior thoracic and subclavian arteries with those of the human subclavian trunk is interesting. The vessel in the porpoise which courses dorsal to the pneumogastric nerve supplies branches which are quite similar to those of human anatomy. The higher intercostals and the deep cervicals are beyond doubt, while the trunk, which on the right side springs from this vessel and on the left from the aortic arch, evidently represents the inferior thyroid. From the other trunk the phrenic artery represents the internal mammary. The cervico-occipital artery of the porpoise simulates very closely the distribution of the transverse cervical and supra-scapular arteries in man, with this exception that the most anterior branch is prolonged to the occiput, a peculiarity which may be connected with the extreme shortness of the neck. But the vessel which I have named superficial thyroid in the porpoise, arising indifferently from the subclavian or carotid stem, seems to find no representative in the human subject unless, indeed, the occasional thyroidea ima be held as corresponding. It is interesting, too, to note the very free anastomosis which is found in the dorso-lateral parts of the neck between the branches of the subclavian and posterior thoracic trunks.

The Rete Mirabile.

Upon the dorsal wall of the thorax, occupying its inner fourth, a large mass of convoluted arteries is to be found spread out as a continuous sheet beneath the pleura.

This rete has received a detailed description from Breschet* and on account of its recognised importance has attracted much attention. Hunter† in 1787 briefly noticed it in the piked whale, and a description is given by Owen‡ of its characters in the porpoise. Of late years, however, an exceedingly interesting account of this

* *Hist. Anat. et Phys. d'un organe de nat. Vasculaire découvert dans Cetacés.* Breschet. Paris, 1836.

† *Loc. cit.* ‡ *Loc. cit.*

rete, as found in the narwhal, has been furnished by Dr. Season Wilson,* and his detailed descriptions throw so much doubt upon the facts of previous observation that further examination is warranted. My dissections in the fœtal porpoise, while they show a state of parts differing very materially from that described by Prof. Owen and earlier observers, yet do not entirely coincide with what has been seen by Dr. Wilson in the narwhal, and it is therefore probable that the anatomy of the rete is not quite the same in all classes of Cetaceans.

Occupying a position on both sides of the vertebral column as above stated, the vascular mass extends forwards for a short distance into the neck. Its posterior limit is marked, upon the right side, by the eleventh dorsal vertebra, while upon the left the extent to which it passes backwards is less by about half an intercostal space. Towards their posterior portions the plexuses of the right and left side are united across the middle line dorsal to the aorta, but in front they are widely separate. The arteries which supply the rete are chiefly the posterior thoracics and the first six aortic intercostals, but branches enter the anterior extremity of each plexus from the inferior thyroid trunk. Close to the roots of the intercostal arteries small vessels also spring directly from the aorta to enter the plexus. Observers differ as to the behaviour of the intercostal trunks. Hunter and Owen speak as if these vessels, upon entering the rete, became coiled up in a manner similar to that in which the spermatic artery is found in the bull; Breschet describes these vessels as if they broke up on entering the rete, and were reformed upon passing out into the intercostal spaces beyond; and Wilson finds in the narwhal that certain of the intercostals are lost entirely in the plexus, and that others, after giving off many branches to it, make their appearance at its outer border, though much reduced in size. In the fœtal porpoise I found all the intercostal arteries passing through the substance of the rete into the spaces beyond, and traced their terminal ramifications to anastomosis with the internal mammary arteries. They are neither convoluted nor coiled, but hold a straight course outwards, surrounded on all sides in the first part of their way by the vessels of the plexus. The rete is formed by long slender vessels which arise from the intercostal trunks, or directly from the aorta; but, although each intercostal artery

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* *Journal of Anatomy*, 14. 1880.

gives off a very large number of such vessels as it is passing through the plexus, its own calibre is at first but little reduced. At the outer border of the rete, however, each intercostal artery sends off a large dorso-spinal branch which passes upwards, accompanied by a deep off-set of the plexus, and after parting with this vessel the intercostal trunk becomes very materially lessened in diameter. Traced still further outwards, it gives rise to two long slender vessels which sweep round the wall of the thorax, between the intercostal muscles. The great diminution in size of the intercostal artery after it has passed through the plexus seems to me important in connection with the physiology of the rete.

The constituent vessels of the plexus are also the subject of considerable difference of opinion. Owen remarks that each individual artery is coiled and may be unravelled for a long distance without lateral branches being found. Wilson, on the other hand, finds a freely-branched network, and characterises it as anastomotic. He subdivides the constituent vessels, from their comparative size, into three sets which he names, vasa maxima, vasa media, and vasa minima. He also describes puckerings upon the walls of some of the vessels. In the porpoise the arteries which enter the rete are nearly all of similar calibre, and though they divide freely the resulting vessels retain very closely the diameter of the parent trunk. Followed from its origin from an aortic intercostal, one of these arteries may be seen to become tortuous as it enters the rete; shortly afterwards it divides, and the arteries which it gives rise to soon divide again. Every here and there upon the course of a tortuous vessel a complicated knot is formed. The knot usually lies in the fork of a division, and one or both of the arteries may take part in it, the vessels being apparently looped and twisted round one another. Any vessel may be traced from one intercostal artery through one or more of such knots to end finally in another intercostal trunk, the same size being maintained through the whole course, spite of repeated divisions. There is thus therefore a perfect inosculation of large numbers of vessels. So far, I have spoken as if the vessels were all of one calibre. Another set of vessels is to be found, however, the arteries belonging to this class being much smaller in size than the others. They seem to be of a transverse or connecting nature, and pass from one to another of the larger vessels. They are usually short straight trunks, but they may run for a considerable distance and in that case they are often slightly tortuous and are branched. I have not been able to find the three kinds of vessels which Dr. Wilson has seen in the narwhal, nor have I noticed any of the puckerings in the walls which he speaks of.

The thoracic rete sends off, opposite each intervertebral foramen, a deep projection into the spinal canal, and a large rete is formed there between the dura mater and the bone. The spinal plexus is largest in the neck where it receives branches from the deep cervical artery. It ceases behind in the posterior dorsal region. Imbedded in the upper part are two vessels which have been described as connected with the posterior cerebral artery.

The generally accepted explanation of the use of these great retia is that they act as stores for oxygenated blood which is brought into use while the animal remains for a long time underneath the water. Pressure of the lungs due to engorgement with venous blood and inflation with air, would doubtless tend to drive the blood from the reservoirs into the circulation. The spinal cord supplied by a rete, in direct continuation with the thoracic plexus, would thus receive pure blood, while the brain, if little were coming to it in the usual way, would get its supply through the posterior cerebral artery from the spinal rete. The posterior thoracic arteries too would carry pure blood back towards the bases of the large trunks which supply the anterior extremity of the body, by which vessels, mixed with what venous blood was coming to the left heart from the lungs, it might be distributed. The small size of the intercostals beyond the rete renders it very unlikely that through them the blood of the plexus reaches the circulation; but on the other hand, the large diameter of the bases of these trunks makes it probable that blood will pass from the rete back into the aorta. If, as I have suggested, such be the case, the pure blood of the rete will reach the great muscles of the tail, mixed, however, with venous blood entering the descending aorta through the patent ductus arteriosus, and also, perhaps, by way of the pulmonary veins through the heart.

DESCRIPTION OF PLATE VII.

SCHEME OF THE ARTERIES OF THE NECK AND THORAX OF THE PORPOISE.

In. Innominate artery.

B. c. Brachio carotid.

C., Carotid; *C. e.*, external carotid; *C. i.*, internal carotid.

h., hyoid; *l.*, lingual; *oc.*, occipital.

S., Subclavian artery; *th.*, superficial thyroid branch; *as. c.*, ascending cervical; *sc.*, scapular; *oc.*, occipital; *e. t.*, external thoracic; *i. m.* phrenic and internal mammary.

Br. Brachial.

d. th. deep thyroid artery.

P. t. Posterior thoracic; *d.*, its dorsal branch.

i. i. Intercostal arteries.

On the right side a portion of the thoracic rete is shown.

pn. Pneumogastric nerve.

VII.

ON THE MORPHOLOGY OF THE CERVICAL ARTICULAR PILLARS; AND ON A LOCK LIMITING EXTENSION OF THE NECK.

By R. Bruce Young, M.A., M.B., C.M.,
Demonstrator of Anatomy.

PLATE VIII.

My attention was drawn to the specimen figured in the Plate by the fact that the ordinarily described roughnesses, which mark the bony pillars supporting the articular surfaces of the cervical vertebræ, had here risen into more or less distinct processes. These processes are seen to form the continuations upwards and inwards of rough markings, which are situated on the back of the articular pillars, and are most distinct on the right and left sides of the sixth cervical vertebra, and on the left side of the fifth (Plate VIII., *a*). They lie behind and below the upper articular surfaces of their respective vertebræ, those on the left side in the fifth and sixth measuring one-eighth of an inch, that on the right side of the sixth somewhat less. On the right side of the fifth vertebra a mere nodule, slightly raised from the surface, affords a trace of the processes found in the others, while on the seventh, owing to the obliteration of the lateral notch, which in the upper cervicals lies between the articular pillar and the transverse process, the raised marking from which the projection springs is seen (specially on the left side) to pass out on to the back of the transverse process, only a trace of roughness being left behind the articular process. From behind the articular processes in the first dorsal all traces of the projections have disappeared, and on the left side a slight elevation about half way out on the transverse process is all that marks the continuation downwards of the series (Plate VIII., *b*).

With reference to those processes, I examined the cervical vertebræ in thirty-seven cases, and found that in one case the series of distinct though small processes, similar in form and position to those in the specimen figured, was complete on both sides, in the fourth, fifth, and sixth vertebræ. In eight other sets one or more of such projections was present, the series being in these cases interrupted. In the remaining instances the articular pillars, as a rule, presented only the usual more or less well-marked roughness, though indications of the processes in question were present in some. In all the specimens in which the processes were noted they were seen to be confined to the lower of the cervical vertebræ—none being found higher than the fourth. In some instances the change in position of the roughness towards the transverse process is not indicated, as it is in the case figured, in the seventh cervical, and the roughnesses are still altogether confined to the articular pillars of that vertebra.

The occasional occurrence, then, on the cervical articular pillars, of distinct projections, developing in connection with the roughnesses which usually exist there, gives a significance to those otherwise unimportant-looking markings, and seems to point to the presence of an element not generally recognised in the cervical vertebræ.

In order to avoid ambiguity, it may be well at this point to indicate the exact meaning which is attached to certain terms used in the following pages. Retzius (*Müller's Archiv, 1849*, p. 685) distinguished three elements—costal, mammillary, and accessory—in the dorsal and lumbar transverse processes. The costal element is the rib-bearing part. The mammillary and accessory elements affording points for muscular attachment he called "muscle" processes. Cleland (*Nat. Hist. Review, 1863*) has shown that the costal element, forming part of the primary costal arch embracing the visceral cavity, has a very different morphological value from that which can be attached to processes projecting out into the muscular mass. His view makes clear the distinction between costal and "muscle" processes, and constrains us to look on the dorsal transverse as a compound process in which vertebral processes of essentially different characters have been united. The costal process we may call the true or primary transverse process, the mammillary and accessory we may distinguish as secondary processes, and thus prevent misunderstanding.

These roughnesses and occasional processes above described are, then, the continuation in the cervical region of the series of secondary processes which Retzius traced in the lumbar and dorsal vertebræ. In the thorax the secondary processes and the rib-bearing process are united in the transverse process; but here again, in the cervical region, as in the lumbar, they are to a certain extent separated from one another. The serial homology of these parts in the cervical vertebræ in the human subject has, I find, been recognised by Aeby (*Lehrbuch der Anat.*, p. 139) and by Henle (*Anat. des Menschen*, p. 30) among foreign anatomists, but neither of these writers goes into any detail on the subject. Retzius (*op. cit.*, p. 653) points out the existence of mammillary processes in the cervical vertebræ of Myrmecophaga tamandua, but makes no mention of their occurrence in the human subject. Among English writers, Owen (*Comp. Anat. of Vertebrates*, vol. ii., p. 397) describes the five posterior cervical vertebræ of Myrmecophaga jubata as possessing "a metapophysial tubercle on the outer side of the prozygapophysis;" while in *Quain's Anatomy* (7th edition, vol. i., p. 22) allusion is made to the continuation of the series of the mammillary processes in the prominences on the articular processes of the hedgehog and of the armadillo. The only other English work consulted that refers to the existence of these processes in the cervical region is Humphry's *Treatise on the Human Skeleton*, in which, at p. 142, it is stated that "in the neck, faint indications of the upper and lower tubercles" (mammillary and accessory tubercles) "may be detected in the form of slight projections at the extremities of the posterior transverse processes."

The probability of the existence of secondary processes in the cervical, homologous with those in the dorsal and lumbar regions, is strengthened by the occurrence of such processes in the cervical vertebræ in some of the lower animals. Mammillary processes are found (*vide supra*) in two of the ant-eaters, in the hedgehog, and in the armadillo. In the beaver and the tiger these processes are also present. In the tiger, where throughout the vertebral column the series of secondary processes is strongly developed, and can be easily traced as far forwards as the fifth cervical, the homology of the processes behind the articular pillars in the fifth, sixth, and seventh cervicals is all the more plainly indicated by the secondary process in the first dorsal lying, not on the transverse process, but behind the portion of the bone bearing the articular surfaces.

Observation of the form of the cervical vertebræ in the human fœtus reveals the existence of a stage in development in which the portion of the vertebra supporting the superior articular surface bears a much closer relation than it does in the adult to the true transverse process. For, as we pass from older to younger fœtal specimens, the lateral notches between the articular pillars and the transverse processes gradually become less, till, as in the seventh cervical in the adult, the superior articular surface lies on the root of the transverse process. Further, in the cervical vertebræ of a fœtus, measuring about three inches from vertex to coccyx, the lateral ossification indicating the root of the transverse process passes into the projecting mass which bears the upper articular surface, and which is intimately associated with the partly cartilaginous portion, afterwards to become the free transverse process in the adult. These facts of development, when taken along with the existence in the adult of the solid pillars, bearing the cervical articular surfaces, which, even in the adult, are only partially separated from the true transverse processes, and have much more the character of lateral projections from than of simple thickenings of portions of the vertebral arch, seem to indicate that these cervical articular pillars take origin in connection with the true transverse processes, and that therefore the articular surfaces, at least the superior ones, rest on the roots of these processes. This view receives confirmation from the position in the adult, of the superior articular surface in the seventh cervical vertebra on the root of the transverse process, the continuity of the portion of bone bearing this articular surface with the transverse process not being here interrupted by any lateral notch such as exists in the higher cervical vertebræ. The extreme slenderness, too, of the true transverse processes in the upper cervicals when compared with the dorsal transverse processes bears out the notion that the cervical articular pillars really belong, in part at least, to the transverse processes. In this light, the difficulty of accounting for the occurrence in connection with these articular pillars of secondary processes, which, in the dorsal region, are closely associated with the true transverse processes, disappears, and a fresh argument is supplied in proof of the homology of the projections on the cervical articular processes.

As the markings on these articular processes are for the attachments of muscles, we naturally look for some evidence as to their true character from the series of the slips of the deep muscles of the back. Portions of three muscles, viz., the trachelo-mastoid, the complexus, and multifidus spinæ, have attachments to articular processes in the cervical region. The exact point of attachment, however, differs in the different muscles. For while the complexus and the trachelo-mastoid slips are attached to the lateral aspect of the articular pillars, the origins of the multifidus spinæ, and these alone, spring from their posterior surface. Extending, as it does, along the whole length of the column, the multifidus spinæ affords a good guide in the determination of the serial homology of the bony points to which its various slips are attached. Its slips arise in the cervical region, from the backs of the articular pillars; in the lumbar region, from the mammillary processes; in the dorsal, from those points of the transverse processes which correspond with the lumbar mammillary processes. This seems to make it plain that the projections from the back of the articular processes in the cervical vertebræ must represent mammillary tubercles. The intimate relationship which exists between these projections and the multifidus spinæ muscle is shown by their not occurring as a rule above the fourth cervical vertebra, above which the line of origins of the muscle does not extend. If any markings do appear on the articular processes of the third cervical they are very slight.

Corresponding to the movement of the secondary processes from the transverse process of the first dorsal vertebra towards the cervical articular pillars, there is a gradual change in the points of attachment of the trachelo-mastoid, complexus, and multifidus spinæ muscles. The lowest cervical slips of these muscles are found to have passed out on to the transverse processes, so that at the seventh cervical vertebra these muscles, not being attached, as they are above, to the articular pillars, have begun that movement outwards by which they reach towards the tip of the transverse process in the dorsal region. The manner in which the change in position of the origins of these muscular slips takes place seems, therefore, to complete the proof of the presence in the cervical articular pillars of projections which, in the dorsal region, are merged in the tips of the transverse processes.

The not infrequent occurrence of a slight rounded projection from the lower and outer part of the roughness at the back of the articular pillars, as on the left side of the fifth cervical (Plate VIII.), seems to indicate that the accessory processes are also represented in the cervical region.

The recognition of the presence in the vertebræ of the neck of parts in series with the lumbar mammillary and accessory processes, enables us to follow out the true relations of the posterior cervical inter-transverse muscles. When we consider the points of attachment of these muscles, and the position which we have seen the representatives of the secondary processes to occupy in the cervical vertebræ, it is difficult to see how they can be, as Joh. Müller (*Anat. der Myxinoiden*, p. 245) considered them, similar to the *inter-transversales mediales* of the lumbar region, and to the muscles in series with those, viz., the dorsal inter-transverse muscles; but if we recognise the essential continuity of the transverse processes and the ribs in the primary costal circle, and the secondary importance of "the exact place and manner in which they are articulated or ossified to the vertebral column" (Cleland, *loc cit.*, p. 125), then the serial homology of the posterior cervical inter-transverse muscles, with the *levatores costarum*, which are, as Müller has pointed out, the representatives in the thorax of the lumbar *inter-transversales laterales*, is rendered probable. No doubt, the outer part of the lumbar transverse process is considered as serially homologous with a rib (*Quain's Anat.*, 9th edition, vol. 2, p. 24), and so the *inter-transversales laterales* connect succeeding rib-elements, while the *levatores costarum* have their upper ends fixed to the tips of the transverse processes, and in the cervical region the posterior inter-transverse muscles pass from true transverse process to true transverse process. The apparent difficulty, however, of recognising a set of muscles, with different points of attachment in different regions, as forming one series, is got over by taking that comprehensive view of the nature of parts forming the primary costal circle, to which we have alluded, and at the same time bearing in mind the various forms and degrees of development of the costal arch. It may here be noted that a change in the attachment of muscular slips in passing from the dorsal to the cervical regions, similar to that just mentioned, is undergone by the *serratus magnus* in ascending to the neck as *levator anguli scapulæ*. The slips of the *serratus magnus* arise from the ribs, those of the *levator anguli scapulæ* from the posterior tubercles of the cervical transverse processes. So that it seems as if the shortening of the bony element, representing a rib, till it lies in front of the anterior divisions of the spinal nerves had, both in the case of the posterior cervical inter-transverse and of the *levator anguli scapulæ* muscles, left these muscles in the plane of the costal circle, though now attached to the tips of the true transverse processes, and not to the prolongations articulated with them.

The anterior inter-transverse muscles in the cervical region, placed in front of the anterior divisions of the spinal nerves, seem to be in series not with the lumbar *inter-transversales laterales*, but with the internal inter-costal muscles.

LOCK LIMITING EXTENSION OF THE NECK.

A point, which, so far as I know, has not been previously noticed, is the presence, in the upper dorsal region, of an arrangement by means of which a locking of the vertebræ is produced, determining the limit of extension of the neck. Just below the inferior border of the upper articular surfaces in one or more of the upper dorsal vertebræ, there occurs on each side, in almost all the columns examined, a more or less well-marked transverse furrow, bounded inferiorly by a ridge which passes outwards and fades away on the transverse process (Plate VIII., *c*). Between this ridge and the articular surface the groove lies, which in extension of the neck receives the sharp lower edge of the inferior articular process of the vertebra above, and thus helps to check further movement in a backward direction.

In six out of the thirty-two specimens examined, the grooves were not distinct; but in the other instances grooves were present in one or more of the upper dorsal vertebræ, while in ten cases the first dorsal alone had such grooves. Amongst those last, by far the best examples of these grooves occur, having a well-defined lip bounding the furrows posteriorly, and seven out of these ten were specially well marked in this respect.

These locking grooves, then, occur in their most typical form in the first dorsal vertebra, and so are situated at a point just at the root of the freely movable column of the cervical vertebræ, where the upper dorsal vertebræ, both by their comparative fixture and inclination forwards, oppose over-extension of the neck. If we bear in mind the great mass of the extensor muscles in the neck and upper dorsal region, acting in extension of the head and neck, and that the freest movement in the upper part of the column occurs between the lowest cervical vertebræ, while a very sudden restriction of mobility takes place in passing from these to the upper dorsals, it is not difficult to account for the existence of these locks as aids to the limitation of extension, or to understand why they should present their strongest features in the first dorsal vertebra, and should not be found in the lower dorsals.

An interesting proof of the normal function of these grooves is found in their excessive development under pathological conditions. In the skeleton of a hunchback, preserved in the Anatomical

Museum of Glasgow University, an excessive acute curvature in the lower dorsal region has so altered the normal curve of the upper dorsal vertebræ, that, instead of a convexity posteriorly, they present a concavity continuous with the cervical curve; and, being thus thrown into over-extension, nearly all the dorsal vertebræ exhibit a great development of the locking grooves behind the superior articular surfaces.

The locking of bone against bone is exemplified in many of the other joints of the body, *e.g.*, the elbow, the wrist, and the ankle, the principle involved being, as Dr. Cleland informs me, one on which Goodsir was wont to lay great stress, the limit of movement of a joint, according to him, never depending entirely on the resistance of stretched ligament, but rather on the locking of bone against bone.

EXPLANATION OF PLATE VIII.

VIEW OF THE FIRST DORSAL AND LOWER FOUR CERVICAL VERTEBRÆ DESCRIBED IN THE TEXT.

(a) Process on the articular pillar of the fifth cervical. Similar processes are seen on both sides of the sixth, and a trace of such a projection on the right side of the fifth.

(b) Projection from the transverse process of the first dorsal.

(c) Groove for the reception of the lower edge of the inferior articular process of the seventh cervical.

VIII.

ON DEVELOPMENT AND ABNORMAL ARRANGEMENT OF THE INTESTINE.

By R. Bruce Young, M.A., M.B., C.M.

PLATE IX.

The interest attaching to any individual instance of abnormality in bodily structure must always be increased, when, besides describing the peculiarities of the case in itself, we can point to the original pathological interference, and trace, with the aid of development, the mode in which it has led to the divergence from the normal. Sometimes an abnormal arrangement affords a picture, more or less altered in detail by subsequent growth, but still true in its essential features, of the state of matters which existed at the time when the change took place, and thus not only are we enabled to explain the adult condition, but light may conversely be thrown on the mode of development of the parts concerned. Acting on such considerations, I venture to add another to the list of recorded misplacements of the great intestine.

Abnormality.

The subject was an adult male. The cæcum projected into the pelvis, and with the lower part of the ascending colon lay free on the left side of the middle line (Fig. 1, *a*). At a point just over the left common iliac artery the colon first became bound to the posterior abdominal wall. Thence it passed obliquely upwards for about four inches, still in contact with the wall of the abdomen, till it reached a point on the left side of the aorta at the level of the superior mesenteric artery and close to the upper end of the duodenum. Turning abruptly to the left, the bowel now descended as low as the iliac fossa, and thence passed upwards in a series of closely packed convolutions to reach the splenic flexure. In this part of its course the intestine was more or less adherent to the posterior parietes. From the splenic flexure the descending colon ran normally into the sigmoid flexure and rectum.

After turning to the left, the colon in the first 3½ inches of its descent was bound to the upper end of the ascending portion. The membrane by which these parts of the colon were bound together was ½-inch broad, and, posteriorly, the lowest inch of it was not adherent to the abdominal wall, so that inferiorly it terminated in a free margin (Fig. 1, *g*). The stomach lay entirely on the left side of the middle line, its pyloric end not having crossed to the right. The duodenum bound down throughout the whole of its course to the abdominal wall passed into the jejunum on the right of the aorta, consequently the ligament of Treitz was stretched obliquely across the aorta to reach it. The duodenum descended to about an inch above the origin of the right common iliac artery, and from its lower border a frænum extended downwards. This probably corresponds with the similar fold which was found by Mr. Treves in the human fœtus and in animals, and from which he holds that the plica duodeno-jejunalis is developed—its existence in the present case being a persistence in the adult of the fœtal condition.*

The mass of the small intestine lay on the right side—the ileum at its lower end passing across to the left to join the colon (Fig. 1, *d*)—consequently the mesentery sprang from a line descending obliquely from the right towards the left side.

From the ileo-cæcal valve to the anus, the great intestine measured 4 feet 8 inches, the small intestine 19 feet 1 inch from the same point to the duodenum.

As regards their branches and the parts of the intestine supplied by them, the superior and inferior mesenteric arteries were normal,

* Treves' "Anat. of the Intestinal Canal and Peritoneum in Man," pp. 19 and 24. In this connection I should like to say that a renewed examination of the peculiar fold alluded to in my previous paper on "Abnormal Disposition of the Colon" (*Jour. of Anat. and Phys.*, October, 1884), convinced me that, as suggested by Mr. Treves, it was peritoneal. The fold, however, did not spring from the lowest point of the duodenum, for the apex of the curve of the abnormally adherent duodenum round the tip of the gall-bladder must not be confused with the lowest point of its normal bend. It was formed of peritoneum which belonged to the left layer of the meso-duodenum, and it passed down to the upper surface of the left layer of the mesentery. These facts, apart from the existence in the present case, in a very different position, of a fold like the one to which he refers, seem opposed to the conclusion that the fold referred to in my previous case is similar "to the vertical fold in animals." In that instance the fold had, I believe, been produced by the upper part of the duodenal curve having become adherent to the liver round the apex of the gall-bladder, so as to pull out a duplication of the serous membrane.

except that the branches of the superior mesenteric to the small intestine ran towards the right, those to the great intestine towards the left, so that if the ascending colon had been twisted over to the right the branches would have had their normal course.

Explanation.

In the position, on the left side, of the whole of the large intestine, and in the arrangement of the branches of the superior mesenteric artery, this case presents resemblances to others that have been recorded, and like them, seems to point to non-completion of the twist in the developing intestine as the cause of the adult malposition. It differs, however, from the case which I previously described (*loc. cit.*), in that the length of the colon shows no such arrested development as was there present. The great intestine has exactly the measurement given by Mr. Treves (*op. cit.*, p. 8) as the average in the male, so that, while the twist around the superior mesenteric artery as an axis has been interfered with, the cause which led to this has not been such as to affect the growth of the bowel.

The stage of development at which the departure from the normal took place being established by the relation of parts in the adult, we have still to discover a cause for that change, and in this instance the adhesion existing between the upper part of the ascending portion of the colon and the succeeding part of the bowel affords a sufficient explanation. In a human fœtus, 1 inch long from vertex to coccyx, in which the rotation of the bowel has not been completed, the cæcum projects from the primary loop of intestine at some distance from its lower end, and the portion of colon between the cæcum and the neck of the loop lies free and movable, attached only by the mesentery of that loop (Fig. 2). From the neck of the primary loop, the colon passes in a curve to the straight tube leading to the anus. Now if, as the result of some inflammatory process, adhesions were formed between the lower end of the primary loop and the descending portion of the colon, close to the point at which the one curves into the other, then, as development proceeded, further rotation of the bowel would be prevented. Provided that the adhesion were limited, and not such as to prevent the possibility of after-growth, the bowel might go on developing with the surrounding parts, and ultimately the state of matters would be as in the present case. The supposition of such a cause having been in action to prevent the normal passage of the cæcum to the right is borne out by the existence of a membranous layer between the upper end of the ascending part of the colon and the succeeding portion of the bowel. That adhesion was limited in extent is rendered probable by the free growth of the bowel towards the cæcal end of the colon, by the normal descending colon, and by the development under peculiar conditions of a transverse colon, for as such the coils of intestine lying in the left lumbar region and passing up to the splenic flexure must be regarded.

That a portion of the colon enters into the formation of the primary intestinal loop is universally admitted, but it seems to me that due weight has not been given to the influence of this on the manner in which the cæcum passes to its adult position. Tracing the development of the bowel in a series of fœtuses, this part of the colon is found in the younger specimens to be passing in front of and over the small intestine, and is still free from the abdominal wall in the mesentery of the primary loop, while the cæcum is at such a distance from the neck of the loop, that if twisted to the right side it reaches the lower part of the lumbar region just above the iliac fossa. In a fœtus 5 inches in length, the part of the colon to the right of the middle line has, owing to the growth of the bowel itself, and of the surrounding parts, become attached to the posterior abdominal wall by peritoneum forming a meso-colon for this part of the intestine, while the cæcum lies in the right lumbar region at the lower end of the kidney. In fœtuses, up till the time of birth, the state of matters remains pretty much the same.

The generally accepted notion of the progress of development of the large intestine is, that the cæcum, after crossing over the small intestine, passes to the right hypochondrium and then pushes downwards towards its ultimate position, forming the right half of the transverse and the ascending colon. So far from this being the true state of matters, the portion of the colon, from which in normal circumstances the ascending and the right half of the transverse colon are developed, already exists as part of the primary loop, before the twist of the intestine to the right occurs; so that when the rotation does take place, it is the whole loop with its peritoneal surroundings which revolves round the superior mesenteric artery until the cæcum lies in the lower part of the right lumbar region, separated, however, in the first place, from the abdominal wall by two opposed surfaces of peritoneum.

When the bowel becomes fixed to the abdominal wall, the cæcum is already just above the right iliac fossa, and only a slight downward growth is needed to carry it to its adult position. In this connection it is interesting to note that Mr. Treves (*op. cit.* pp. 39 and 40) has pointed out that there never is a meso-cæcum in the human subject, and that the cæcum is entirely covered behind by peritoneum which is, in the majority of cases, reflected from the posterior surface of the ascending colon—the commencement of the ascending colon, as well as the cæcum, being thus completely invested by the serous covering. This seems to confirm the idea that the attachment of the cæcal end of the colon in the lower lumbar region is followed by a growth downwards of that portion of the bowel carrying with it a complete covering of peritoneum.

The portion of the colon to the right of the middle line, when it becomes attached to the posterior abdominal wall, has, as Mr. Treves (*op. cit.*, p. 52) recognises, an oblique course running from the right side below upwards towards the splenic flexure, and this disposition is "still marked in the fœtus at full time, and even in some young subjects." The obliquity in position of this part of the colon Mr. Treves associates with the great size of the liver, and he further states "that it is not until the liver has regained its normal proportions with reference to the other viscera that the hepatic flexure becomes well marked, and the right segment of the colon acquires the position that is familiar in the adult." Even in the adult the hepatic flexure is often ill-marked, and, compared with the splenic flexure, is always of less importance, both as regards distinctness and date of appearance.

Those cases in which the cæcum in the adult occupies a situation on the right side higher than the lumbar region are, in the light of the present facts, probably to be accounted for by some interference with the growth of the colon at a time when the primary loop still lay free in the abdominal cavity, the part of the colon to the right of the middle line not yet having been bound to the posterior abdominal wall.

ADDITIONAL OBSERVATIONS ON DEVELOPMENT OF THE INTESTINE.

In the foregoing remarks the development of intestine has been alluded to only in so far as it concerned the instance of malposition described, but the opportunity may be taken of directing attention to a few other points which have come under the writer's notice when making examination of fœtal conditions required in that connection.

In the fœtus referred to (Fig. 2) the duodenum curves underneath the root of the superior mesenteric artery, carrying with it the upper end of the jejunum. Even at this early stage, before the part of the colon at the neck of the primary loop has reached farther than the left side of the superior mesenteric artery, the duodenal curve has been formed. Thus, while no doubt growth in opposite directions at the two ends of the primary loop causes rotation of the bowel, it is probable that the passage of the lower end of the duodenum with the upper end of the jejunum underneath the artery determines the direction of this rotation.

As regards the distribution of the superior mesenteric artery, there is a point to which I wish to direct attention. This artery forms the axis round which rotation of the primary loop takes place, and from its opposite sides come off the vasa intestini tenuis and the colic branches. Thus the part of the ileum belonging to the inferior limb of the loop receives its blood-supply, not from the vasa intestini tenuis, but, as Tiedemann correctly represents, from the anastomosis between the ileo-colic branch and the termination of the main trunk of the superior mesenteric artery. The length of the part of the ileum so supplied (taking the ileo-colic junction and the prolongation of the line of the stem of the superior mesenteric as limits) varied in the cases which I examined, from 1 foot some inches to 3 feet. This represents in the adult the portion of the ileum, which was inferior to the apex of the primary loop—its upper limit marking the position of that apex. In connection with this it is interesting to note the position at which true diverticulum of the intestine occurs. In eight specimens obtained from the dissecting rooms and preserved in the Anatomical Museum of the University of Glasgow, the recorded measurements of the distance of this diverticulum from the ileo-cæcal junction range from 20 inches to 4 feet.

The stages of development of the sigmoid flexure do not seem to have been up to the present described. In a fœtus, 3 inches long, I find the colon descending in a comparatively straight course from the well-marked splenic flexure, until at its lower part it bends backwards towards the posterior abdominal wall, and, entering the pelvis, passes down to the anus. The free meso-colon is still attached to the posterior abdominal wall, between the left kidney and the middle line; and there is no sigmoid flexure. At a later stage, in a fœtus about five inches in length, the colon is arranged round the outer border of the kidney, which is relatively very large (Fig. 3). The line of attachment of the descending colon to the posterior abdominal wall is now external to the left kidney, and its meso-colon has been obliterated. From the outside of the kidney the bowel curves inwards round its lower end, and then passes into the free loop of the sigmoid flexure. The appearances suggest that the kidney, in its rapid increase, has encroached on the left layer of the primitive meso-colon, while the growth of the abdominal wall has pulled that layer to the side, and thus the colon is laid along the outer and lower borders of the kidney, leaving the lower part of the bowel with its free peritoneal attachment. The part of the colon which curves round the lower end of the kidney forms, with the part above described as bending back to enter the pelvis, the neck of a loop, which, left with a free meso-colon, projects upwards and towards the right (Fig. 3, *c*). This Mr. Treves recognises (*op. cit.*, p. 62) to be the condition of the sigmoid flexure in a fœtus of 5 inches. Thus the sigmoid flexure is formed with a meso-colon, representing the lower and somewhat displaced part of the primitive mesentery. The persistence of the free meso-colon of the sigmoid flexure is probably to be associated, not only with the existence of this loop of bowel, but also with the fact that the demands upon the peritoneum in this region are less than elsewhere in the abdomen.

In the fœtus, whose intestines are represented in Fig. 2, a curious condition of the cæcum is seen. Here, instead of a single primitive cæcum, there project from the great intestine, at its junction with the ileum, two small pouches, that on the left side being slightly the larger. Meckel (*Tabulæ Anatomico-pathologicae, Fascic.* III., *Tab.* XXIII., Fig. 9) figures a case in which the cæcum was bifid and alludes (*Fascic.* III., p. 14) to two other instances of a similar kind.* Unfortunately, owing to want of material, I have not had an opportunity of examining, on this point, other human fœtuses of a similar or an earlier date; but the existence, among mammals, of two cæca in the armadillo, two-toed anteater, and manatee, and the characters of the vermiform

* Mr. Lockwood (*Brit. Med. Jour.*, 1882, vol. ii., p. 574) refers to Fig. 4 of the same Plate in Meckel's work as representing a case in which there were two *cæca*, but the description of that Figure shows that it was the rectal end of the colon that terminated in two blind pouches (*saccis cæcis*).

appendix in the wombat, as well as the adult condition in the human subject, seem to point to the possibility of extended observation, which I hope to carry out, revealing in the fact here noted a significance beyond that which attaches to it as a casual peculiarity.

EXPLANATION OF PLATE IX.

Fig. 1.—Misplacement of the colon described in the text. The liver has been turned upwards to afford a better view of parts.

a. Cæcum lifted out of the pelvis.
b. Duodenum.
c. Jejunum.
d. Ileum crossing to the left to join the great intestine.
e. Beginning of transverse portion of the colon.
f. Sigmoid flexure.
g. Membrane binding together parts of the ascending and transverse portions of the colon.

Fig. 2.—Enlarged view of stomach and intestines of fœtus 1 inch long. The liver has been removed.

a. Remains of umbilical cord.
b. Coils of small intestine which lay in the neck of the umbilical vesicle.

In the upper part of the Figure, the stomach and the beginning of the duodenum are seen. The lower part of the duodenum, carrying with it the upper end of the jejunum, curves beneath the superior mesenteric artery, and consequently these parts of the intestine are hidden from view. From the bifid cæcum the great intestine can be traced up to the neck of the primary loop, where it passes into descending colon.

Fig. 3.—Descending colon and sigmoid flexure, with left half of transverse colon of fœtus, about 5 inches long.

a is placed on the peritoneum covering the left kidney.
b. Descending colon.
c. Sigmoid flexure.
d. Left half of transverse colon.

IX.

NOTES ON THE VISCERA OF GYMNOTUS ELECTRICUS.

By Professor Cleland.

[Read at the Meeting of the British Association at Aberdeen, Sept., 1885.]

PLATE X.

Naturally by far the greatest interest attached to *Gymnotus electricus* is in connection with its electric organs, both because its batteries are so much more powerful than those of any other fish, and because electric organs are structures found in so few genera so widely removed, and, although possessing certain characters in common, differ so much one from another in structure and situation. Thus, a certain homology may perhaps be made out between the inferior batteries of *Gymnotus* and the "pseudo-electric" organs in the tail of *Mormyrus*, as also between the two pairs of batteries of *Gymnotus*, and the pseudo-electric organs of *Gymnarchus*, described by Erol (*Stannius Zootomie d. Fische* 2te *Auflage*, p. 123), but the batteries of *Gymnotus*, lying between the muscles and supplied by the spinal cord, are not in the slightest degree homologous with those of the only other teleostean genus which gives a shock, viz., *Malapterurus;* for the batteries of *Malapterurus* are unconnected with the muscles of the trunk, are connected closely with the skin, combining to surround the whole body, and are supplied by a single pair of nerves from the neighbourhood of the brain. Still more remarkable is it that the pseudo-electric organs found in the tails of Skates, placed longitudinally where muscles might have been expected, are capable of comparison with the electric organs of *Gymnotus*, but have no homology whatever with those of the nearly allied genus *Torpedo*, which are vertically placed in front of the pectoral fins, and supplied by a special pair of nerves from the medulla oblongata. But though I thus take this opportunity of directing attention to facts which cannot with impunity be overlooked in searching for that great desideratum—a correct doctrine of evolution, my object in the few remarks which follow is simply to point out in the visceral anatomy of *Gymnotus electricus,* some curious peculiarities which might perhaps have been better known had not the interest of its electric powers distracted attention from them.

The remarkable spongy growths of the mucous membrane of the mouth and pharynx are known, and are alluded to by Günther (Cat. Fishes of Brit. Mus., VIII., p. 10), in the perfunctory description, " Mucous membrane of mouth, with numerous lobes." Bloch wrote about a century ago, " La langue est large et pleine de verrues ainsi que le palais" (*Ichthyologie,* V. 39). Their anatomy, however, does not seem to have been minutely studied, and it is with surprise that I find them to be erectile and of very peculiar structure. They are folds of the mucous membrane, each side of each fold having its own branches of artery ramifying subjacent to a felted fibrous membrane which everywhere forms the cutis vera of the buccal cavity. The folds are in rows, two placed longitudinally, one on each side of the roof of the mouth, meeting its neighbour in front, and a pair external to these; while others clothe the inner edges of the branchial arches, and are continued transversely across the middle line in a series of papillated ridges similar to those on the roof. The arteries which I have mentioned come off in the roof of the mouth from two pairs of trunks, from the roots of the aorta, gorged with blood in the specimen from which I write, and giving off great numbers of branches, spreading transversely, and freely anastomosing. The veins are superficial to these, in an irregular network, which I found difficult to investigate on account of the thinness of their walls. The fibrous dermal membrane is pierced all over with apertures, through each of which an arteriole passes to divide up into about half a dozen close-set branches, which seem to terminate abruptly on the surface, each in a dilated and depressed extremity. (Figs. 2 and 3.) A thin layer of horny epithelium covers them, presenting a shallow honeycomb depression for each of these. The mode of connection of this arrangement of tufts of simple-walled vessels with the veins was not made out.

It is not easy to make sure what purpose these structures serve, but, on the whole, I incline to believe them to be supplemental organs of respiration, and this even on the supposition, which I think probable, that they all receive their blood from vessels emerging from the gills. The pseudobranchs found in many fishes were shown by Müller in his memoir on the Myxinoid fishes, to get their blood from the branchial veins, much after the fashion in which, so far as I can see, these fungoid structures receive theirs. Yet morphologically the pseudobranchs are in series with the true gills, and though the nature of their blood-supply has led to the allegation that they cannot be respiratory, the assertion must not be too rashly made. It passed muster excellently well in the days in which it was supposed that want of oxygen to act on the impure blood going to a respiratory organ led to stasis of blood in the organ, by hindering its movement forward. But it has been shown from the experiments of Reid and others (Flint, Physiology of Man, I., 291), that the blood in asphyxia is not obstructed till it reaches the systemic capillaries. The blueness of the skin in asphyxia shows the presence of quantities of unoxidized blood there, and it is matter of notoriety which any practitioner or sick nurse may observe, that the body of a person who has died from bronchitis, or any such affection as leads to stagnation of dark blood in the capillaries, may become red-lipped and rosy in colour on prolonged exposure to the air. There is nothing to hinder the possibility of pseudobranchs and this peculiar arrangement of the mucous membrane of *Gymnotus* exercising a function as supplemental respiratory organs when the blood has passed through the gills without being properly oxidized. It suggests itself, therefore, as possible that at times, as when the ponds in which it occurs are foul from heat and evaporation, the *Gymnotus* replenishes the deficient oxygen of its blood by approaching its mouth to the surface, so as to allow the air to act on the tufts of dilated capillaries in its buccal membrane, just as in a number of other teleostei of different families, *e.g. Saccobranchus, Clarias, Heterotis, Polyacanthus,* and *Osphromenus,* there are supplemental respiratory arrangements of extraordinary kinds, useful when water is deficient.

The next point to which I would call attention is the arrangement of the swimming bladders and their ducts. Stannius (*Zootomie der Fische*, 2nd edition, p. 225) refers to a memoir by J. Reinhardt, from which he gives the following abstract:—"All *Gymnotini* possess, as Cuvier has already pointed out, two swimming bladders, an anterior smaller, and a posterior larger, and often very long. From the hinder end of the anterior swimming bladder springs a fine canal which has the length of the bladder, and binds it to the fore end of the posterior bladder. From this canal, but quite near to where it opens into the posterior bladder, the fine ductus pneumaticus comes off, which opens on the dorsal wall of the œsophagus near its passage into the stomach. Reinhardt has examined the genera *Carapus*, *Sternopygus*, and *Sternarchus*."

I have not had the opportunity of examining any of these genera; but, as seen in the specimen before me, the disposition of parts in *Gymnotus electricus* differs in certain not unimportant respects from this description. The duct of the anterior bladder does indeed come off from its hinder end, and the duct of the posterior bladder from its fore end; but the bladders are far apart, and the duct of the hinder bladder runs a much longer course than that of the anterior bladder before the two join to form the pneumatic duct which opens into the œsophagus. The kidneys occupy nearly the whole length of the abdominal cavity, and are thoroughly conjoined, except at the fore part, where they embrace the anterior bladder, which is quite a small structure, not longer than broad. The fore end of the posterior bladder fits closely to the swollen hinder end of the conjoint kidney, and its duct passes forward on the left side of the single ureter, perforating the swollen end of the kidney, as has been pointed out by Hyrtl (*Denksch. d. Kais. Akad. Wien*, 1850, "*Das uropoetische System der Knockenfische*, p. 86). The duct of the anterior bladder makes direct for the œsophagus, and after traversing two-thirds of the distance, is joined at an angle by that of the posterior bladder.

The position of the posterior duct, on one side of the ureter, is easily understood, when it is remembered that swimming bladders are developed as outgrowths from the œsophagus, and that the disappearance of the communication in cases of ductless swimming bladders is a peculiarity of later development. The perforation of the kidney by the posterior duct is easily accounted for on the supposition that by redundant growth at its back part the kidney has surrounded the duct. The disposition in *Gymnotus* suggests bifurcation of the pneumatic duct in the process of elongation, and while the condition found by Reinhardt in other genera, were the condition in *Gymnotus* not taken into consideration, would suggest a primitive single swimming bladder, subsequently constricted so as to form two.

Immediately behind the orifice of the pneumatic duct the œsophagus expands somewhat into a large and strong-walled stomach, which terminates in an exceedingly contracted pylorus, so contracted that, in the specimen before me, an ordinary silver probe could not be passed through it. Opening into a recess on the intestinal side of the pylorus is the gall bladder—a structure of very great proportional size—which, though prolonged into a fundus blind and free, is formed by dilatation of the bile duct, as it is in a number of other fishes, and receives about its middle separate ducts from the different hepatic lobes. Immediately beyond the opening of the gall bladder are about eight more depressions, opening mostly in pairs, on the anterior margin of the intestine, and into these open groups of short cæca crowded together, the pyloric appendages. The intestine then passes back round the fundus of the stomach, is prolonged forward in a single loop nearly to the œsophagus, returns to the posterior extremity of the abdominal cavity, where it is bound down, and finally passes forward to the vent.

The vent is placed unusually far forwards, being in fact opposite the bulbus arteriosus, and in front, therefore, of the liver and heart; and in connection with this there is a most striking and curious arrangement of parts along the ventral wall of the abdomen. As the intestine passes forward the whole length of the abdominal cavity to the vent, there lies on its under side a long urinary duct as wide as itself in its appearance when undisturbed, and capable of considerable expansion, its walls being thrown into longitudinal folds. It arises by a short and narrow ureter from the hinder expansion of the kidney, and ends in a wide orifice immediately behind the vent. On the sides of this lie the ovaries, which in my specimen are small, the ova being unripe and disposed in folds of the lining membrane. Each ovary has its extremity directed backwards, and passes forward to be continued into a duct about half as long as itself; and the two ovarian ducts open separately into the renal duct on its dorsal side, immediately within its outlet. I have not met before with any instance of ureter and ovaries so completely turned round to occupy a ventral position and be directed forwards in their whole length; but the same thing occurs to a smaller extent sometimes, and Hyrtl (*op. cit.*, plate X.) has figured the urinary bladder inserted in the same fashion in *Trachinus draco*, and in *Cepola rubescens.*

EXPLANATION OF PLATE X.

Fig 1.—*Viscera of Gymnotus*, (*a b c*) mucous membrane of roof, sides, and floor of buccal cavity, with rows of spongy prominences; (*d*) gills; (*e*) auricle of heart; (*f*) right lobe of liver; (*g*) gall bladder; (*h*) stomach laid open; (*i*) duodenal dilatation, with the depressions by which the numerous pyloric glands open into it; (*k*) kidney; (*l*) rectum; (*m*) elongated urinary duct, with the oviducts running along its deep surface; (*n*) ureter; (*o o*) ovaries; (*p*) anterior swimming bladder, with its outer coat torn from its attachments; (*q*) anterior extremity of posterior swimming bladder, with its outer coat torn from its attachments; (*r*) common pneumatic duct, formed by the junction of the special ducts of the two swimming bladders, and opening into the œsophageal part of the stomach.

Fig. 2.—Tuft of vessels from the buccal mucous membrane, magnified.

Fig. 3.—Terminal dilatations of the same vessels, more highly magnified.

X.

ON CERTAIN DISTINCTIONS OF FORM HITHERTO UNNOTICED IN THE HUMAN PELVIS, CHARACTERISTIC OF SEX, AGE, AND RACE.

By Professor Cleland.

PLATE XI.

1. *Os Pubis.*—A distinction between the male and female pelvis which has lately come under my notice in conversation with Mr. Christie, the Preparator of the Anatomical Museum, is one which I think worthy of special notice. It is this:—The distance between the lines marking the inner limit of attachment of the femoral muscles on the right and left side is considerably greater in the female than in the male. In a middle-aged or old female pelvis the line in question will always be seen marked by a distinct ridge, with a flattened surface extending inwards from it, covered in the recent state by the superficial ligament of the symphysis; and the distance between the two ridges of opposite sides will be found to increase as the pubic arch is approached.

It is to be noted with regard to this distinction that it has great constancy. The obstetrician knows well that the pelvic cavity is not always more spacious in the female than the male, neither is its axis always shorter, nor the pubic arch in every instance possessed of greater width than is to be found in many a male pelvis. But the character now mentioned is to be depended on, provided ossification is thoroughly completed. The weak point of the character is that it is difficult to apply in the case of a young adult. The statement that the iliac and ischial epiphyses may not be completely united to the main bone till the 25th year, is probably correct. I note further, that in the female pelvis the ischial epiphysis unites earlier than the iliac, though I have seen the contrary in the male pelvis. But the os innominatum is complete at both of these places considerably earlier than at the symphysis. Too much has been made of the occurrence of an epiphysis at the symphysis pubis. I have not seen a continuous thin plate of bone at that part, but only irregular nodules, and these may be found distinct after the bone is everywhere else complete. Probably ossification at this part is completed earlier in the male than in the female.

2. *Iliac Divarication.*—With regard to the expansion of the iliac bones some curious statements have crept into Quain's Anatomy. In the seventh and eighth editions the questionable statement, not found in previous editions, was made, that in the female "the ilia are more expanded than in the male." In the ninth edition it is announced that "the ilia are more vertical, and thus the false pelvis is relatively narrower than in the male." The word "relatively" has probably reference to the greater breadth of the true pelvis in the female; but the first part of the statement is that which demands particular attention.

I have examined the anterior edges of the ilia in 14 adult male and 16 adult female pelvises, and find that there is considerable variation in the angle at which the right and left lie to one another, but that the variation does not depend on sex. The average angle of divarication in the female was 50½°, the average in the male was 53°. In three males the divarication reached to 73°, 80°, and 89°, and all three specimens were evidently from muscular subjects of middle age or beyond it, and heavily made.

In one male pelvis, a negro, in which the iliac and ischial epiphyses were just beginning to unite with the main bone, the angle was only 16°, and in another male in which the ischial epiphysis had begun to unite, and the iliac had not, the angle was 22°. Among the 16 female pelvises there was one with the epiphyses quite united, with an angle of divarication of the ilia measuring only 22°; while there were five others, all of them with the epiphyses incompletely united, which had respectively angles of 31°, 33°, 34°, 35°, and 41°. Only one of the others had the epiphyses not quite completely united, and it had an angle of 65°. One ill-shaped pelvis, from an elderly and peculiarly-made subject, had an angle of 81°; another, heavy and large, had an angle of 76; the remainder varied from 48° to 64°.

I have examined, in addition, a few young skeletons. In four subjects with milk-teeth the angles of divarication are 86°, 85°, 85°, 82°; in two other subjects which have the permanent incisors the angles are 64° and 61°; in another, with only the two first incisors of the lower jaw replaced, the angle is 79°, and two older adolescents have angles of 58° and 50°. This makes it evident that the divarication diminishes from childhood to early adult life, while it is equally evident that after adult life is reached the divarication tends again to increase.

This increased divarication of the iliac blades, occurring, as it does, after ossification is completed, is doubtless the result of muscular traction, the gluteus medius and minimus muscles pulling upon the ilium in every step in walking, as well as in the stand-at-ease position. But the diminution of divarication in adolescence, a circumstance to which attention seems to be now called for the first time, depends on a remarkable rotation of the pelvic bones during growth. If the sacrum of an adolescent be looked at from the front, its lateral margins will each be seen to present a marked concavity opposite the junction of its first and second vertebræ, while in the adult no such concavity exists. It has disappeared by the second vertebra becoming broader in proportion to the breadth of the first; and thereby the ilium is rotated round a line extending from the basal or anterior end of its auricular surface forwards to the symphysis pubis. Thus, the iliac blades are made more vertical at the same time that the cavity of the pelvis below the brim is made more capacious.

I am again indebted to Mr. Christie for pointing out to me a peculiarity in the ossification of the sacrum connected with this rotation, namely, that the lateral epiphysis supporting the auricular surface uniformly becomes united by osseous tissue to the main bone at its basal end before it is united in the rest of its extent. The breadth of the sacrum opposite its first vertebra is thus checked by the anchylosis of the epiphysis before the expansion of the second vertebra is interfered with.

Doubtless, also, the body of the pubic bone continues to grow more rapidly towards the perinæal border of the symphysis than at the abdominal border, but it is difficult to obtain proof of this apart from the changes in the iliac bones and sacrum.

3. *Changes in form of Brim.*—Litzmann,* to whom reference is made by Matthews Duncan in his valuable Researches, remarks that "up to the age of 13 the transverse diameter of the brim is sometimes less than the conjugate, but after that age it is constantly greater." Matthews Duncan† epitomizes the changes occurring

* Die Formen des Beckens, Berlin, 1861, p. 32.

† Researches in Obstetrics, pp. 110 and 111.

during growth in the statement that "the transverse diameter of the brim is greatly increased at the expense of the antero-posterior or conjugate." "This transverse enlargement," he points out, "is powerfully resisted by the pressure upon the acetabula." And he further explains convincingly that "the weight on the upper end of the iliac beam tends to draw it inwards, the auricular portion of the sacrum being the fulcrum upon which the beam rests. In proportion as the upper end of the beam is dragged inwards, will the lower end tend to be projected outwards, and the transverse diameter of the pelvis be increased. . . . . The bone does slightly bend about midway between its auricular surface and its lower end. But although it bends under the influence of these forces, its lower half is, as a whole, to some extent projected outwards."

But this, important as it is, is not all; there are other changes which take place with growth, and other mechanisms by which they are produced. So far as a limited, but, I think, sufficient number of specimens allows me to judge, the conjugate and transverse diameters are about equal in young children, while at a later period, extending probably from about six to thirteen years of age, the conjugate diameter grows more rapidly than the transverse, and after that age the adult form is approached.

Comparing new-born children with the adult, Litzmann states (p. 25):—"At the sides of the upper pelvic arch, the hinder ends of the iliac bones, from the posterior superior spine to the anterior superior angle of the auricular surface, are shorter in proportion to the foreparts, from the anterior superior angle of the auricular surface to the ilio-pectineal tubercle. Still shorter proportionately are the limbs of the inferior pelvic half-ring, from the ilio-pectineal tubercle to the middle of the upper edge of the symphysis pubis." The first of these statements may be supplemented by pointing out that the iliac bones project behind the base of the sacrum very little until after puberty. This seems to indicate an increased development of the muscles of the back at the same time that the pelvis assumes its adult form, and becomes the more constantly selected fulcrum for the movements of the trunk, while the muscles of the lower limbs also become more developed in harmony with the more extensive leverage and surfaces of attachment afforded by the pelvis. The scampering, scrambling, and lounging of boyhood and girlhood are exchanged for a more habitually upright attitude in walking, standing, and sitting. The mode of growth of the great post-sacral muscular fossa will be better appreciated by noting that after puberty in European and other pelvises, not only does the base of the sacrum increase in breadth compared with the distance between the transverse processes of the last lumbar vertebra, but the crests of the ilia which had previously fallen short of the level of the under borders of these processes rise above the level of their upper borders. Thus, plainly there is a connection between the separability of the epiphysis of the iliac crest and the extent and depth of the post-sacral fossa, just as there is between the breadth of the fossa and the separability of the lateral sacral epiphyses.

As regards the second statement in the passage just quoted from Litzmann, it also bears expansion. After examining a number of specimens, I have arrived at the conclusion that from infancy to puberty the length of the pubic bone from the symphysis to the acetabular extremity within the pelvic brim is equal to the distance from the latter point to the most projecting part of the articulation with the sacrum, while at birth the first of these distances is shorter than the second. I have measured the distances in a straight line, and may term them the lengths of the pubic and iliac parts of the brim. They are equal up to puberty, but in the European adult the pubic exceeds the iliac length from a quarter to three quarters of an inch. This is to a certain extent to be accounted for by the consideration that the iliac part of the brim cannot be lengthened except by addition to its acetabular extremity, while the pubic part can be lengthened both at its acetabular end and at the symphysis; that, further, the sutures of the acetabulum become obliterated about puberty; and after that occurs the iliac part of the brim is incapable of elongation, while growth at the symphysis continues, as I have mentioned, till adult life. It sometimes, however, happens in a pelvis not of the most capacious or regular shape that excess of the length of the pubic over the iliac part of the brim depends on the iliac part having yielded and become highly concave in the way alluded to by Dr. Matthews Duncan.

In endeavouring to understand the mechanism of the changes in the pelvic brim during growth, it is necessary to study the mode of growth of the sacrum in width, and the details of the post-sacral part of the ilium. The width of the sacral canal does not increase in later adolescence as the width of the whole sacrum does. It is well known that the bodies of the upper sacral vertebræ are broader in proportion to the whole width of the bone in the young sacrum than in the adult. This growth outwards of the lateral masses or costal elements not only increases the distance of the anterior sacral foramina from the edge of the bone, but has the same effect on the position of the posterior sacral foramina. The strong posterior sacro-iliac ligaments are attached to the surface external to the posterior sacral foramina, the surface which is thus rapidly growing. The post-auricular part of the ilium also grows rapidly, and in the adult is divided into two parts, a posterior and upper part which is rugged and rough, as places of attachment of strong ligaments are wont to be, and a depressed part intervening between this and the auricular surface. This depressed part is smooth and close-grained, with none of the appearance of giving attachment to strong ligaments, and in point of fact has areolar tissue loaded with adipose vesicles in contact with it. This depressed part forms an elongated groove dorsal to the auricular surface, and opposite its hinder end, between the two posterior iliac spines, one can perceive a separation between the inferior fibres of the posterior sacro-iliac ligament and a strong bundle of fibres constituting an *inferior sacro-iliac ligament* continuous with the thinner anterior sacral, but extending between the posterior inferior iliac spine and the side of the third sacral vertebra.

It cannot be supposed that the close-grained surface, often figured, but little appreciated, to which I now draw attention, has resulted, contrary to the law of osseous growth, by interstitial expansion of the ilium at this part, and therefore we must conclude that the posterior sacro-iliac ligament has new fibres added to it superficially while the original fibres become wasted.

The important points, as bearing on the shape of the brim, are that the widening sacrum throws the iliac bones outwards at the auricular surfaces; that the posterior iliac ligaments pull their hinder ends downwards, and that thus it is with increasing leverage that those ligaments push the acetabular ends of the iliac part of the brim outwards, as Dr. Matthews Duncan pointed out. The pubic parts of the brim, by pressure at the acetabula communicated by the iliac bones, lie at a larger angle one to the other, and, continuing to grow at the symphysis, may even aid in pushing the acetabula outwards.

It is curious to note that in a series of twenty adult male and female British specimens, the two in which the iliac length was found to approach most nearly to the pubic length were the only two females in which the conjugate diameter distinctly exceeded the transverse, and in both instances the iliac part of the brim was positively elongated, and the pubic part not shortened. The weight of the body appears to be an important element in producing the lateral expansion of the brim, and it would be interesting to know if unbroadened brim results from long sickness and confinement to the reclining posture in adolescence. If that has been the cause of the greater conjugate than transverse diameter in the two pelvises referred to, then their increased iliac length of brim is another instance of exaggerated growth resulting from absence of normal pressure, in the manner pointed out by Dr. Allen in congenital luxation of the radius. (*Glasgow Medical Journal*, July, 1880.)

4. *Unbroadened Pelvis of the Bosjes and other Races.*—I have before me a well-authenticated skeleton of a Bosjes female. The pelvis conforms exactly to the description and figure of a female pelvis of the same race given by Sir William Turner.* But I gather further from the figure that the Edinburgh specimen agrees with that in the Anatomical Museum of this University in a remarkable character which seems to have escaped attention. The back part of the crest of the ilium falls short of the level of the transverse processes of the fifth lumbar vertebra, a character correlated with feeble development of the iliac blades. The auricular surface is narrow, and the post-auricular part of the ilium curiously deficient in growth, the back part of the crest being nearly parallel with the ventral margin of the auricular surface. This parallelism of the back part of the iliac crest with the front of the auricular surface is dissimilar to the form of the European whether adult or in infancy, and seems to depend on feeble development of the whole iliac blade. But the remarkable want of projection behind the sacrum and shallowness of hollow for the origin of the multifidus spinæ muscle, is a continuance in adult life of the condition to which I have called attention as existing before puberty in the European.

It is further to be observed that not only has the Bosjes woman the unbroadened pelvic brim, resulting in long conjugate as well as narrow transverse diameter, but she has the pubic and iliac

* Report of Voyage of H.M.S. *Challenger*, Zoology, vol. xvi., p. 56. To this memoir reference may be made for a bibliography of the pelvis.

parts of the brim equal in length, like the European pelvis at puberty. Yet the broad interfemoral surface at the side of the symphysis, the female peculiarity pointed out in this memoir, is well marked, showing that the relative shortness of the pubic part of the brim is not from mere premature ossification of the part latest to be completed, namely, the symphysial surface.

The unbroadened brim may well be attributed partly to the lightness of the upper part of the trunk, but still more to the deficient post-auricular growth of the iliac bones furnishing but little leverage for effecting the expansion which occurs in the European pelvis after puberty.

I prefer to speak of an *unbroadened* pelvic brim rather than to use such a word as "dolichopellic," not only because the plain word is more grateful to the ear, but because it expresses the fact of the non-occurrence of that process of broadening after puberty, the mechanism of which was first explained by Matthews Duncan, and because I question the value of the numerical indices associated with the compounds beginning with *dolicho*, *brachy*, and *mesati*, even although they are fashionable.

With regard to the relation of unbroadened brim to racial habits, it will be noted that the feeble development of the post-auricular iliac levers bears on this question, for it seems safe to suppose that a shallow post-sacral fossa can contain but a feebly-developed multifidus spinæ muscle, and that this is likely to be associated with disinclination to prolonged use of the erect posture, while on the other hand, increased use of that posture is likely to increase muscular growth, and thereby foster post-auricular iliac growth, which, in turn, by lengthening the levers on which the posterior sacro-iliac ligaments pull, will favour lateral expansion of the brim. I have no doubt whatever that in the Australian pelvis there will be found deficiency of post-auricular iliac projection similar to that in the Bosjes.

The angle of divarication of the anterior edges of the iliac blades in this Bosjes pelvis is 37°. The epiphyses are all thoroughly united.

EXPLANATION OF PLATE XI.

1. Left pubic bone of a middle-aged female, showing in front of the symphysis, prolonged up from the inner surface of the descending ramus, the flat surface characteristic of the female sex.

2. Right pubic bone of a male to contrast with the preceding figure, showing in front of the symphysis a narrow rough edge continuous with the inner surface of the descending ramus.

3. Auricular and post-auricular surfaces of the right iliac bone of an adult European female.

4. Inner surface of the left iliac bone of a child at birth.

5. Auricular and post-auricular surfaces of the right iliac bone of an adult Bosjes woman. Compare with figures 3 and 4.

XI.

ON THE SKELETON OF THE TAIL IN MYXINE AND PETROMYZON.

By Professor Cleland.

PLATE XII.

The exact position of the cyclostome is a subject on which opinions various, and some of them hazy, are held. In days when animals were arranged in linear series, the osseous fishes deemed the highest and the plagiostomes placed lower in the scale, there was little difficulty in settling that the cyclostomes came between the plagiostomes and Amphioxus. Those days are past. But the appreciation of affinity between the cyclostomes and plagiostomes, which is apparent throughout the great work of Joannes Müller on the "Comparative Anatomy of the Myxinoids," is a just appreciation; and while the lampreys and myxinoids have such extraordinary modifications of mouth, nose, and throat as mask, almost beyond recognition, the resemblance of their heads to those of other fishes, and indicate them to be highly aberrant from the main line of the advance of life, the anatomy of the rest of the body, and especially the brain, vertebral column, and tail, show how nearly they are allied to the elasmobranchs. But the tail, perhaps on account of its simplicity, has not received the attention it deserves.

In macerating a Myxine with a view to studying its skeleton, I was surprised to find beneath the notochord, at its hinder end, a cartilaginous structure of unique appearance, which had apparently altogether escaped the observation of previous dissectors. I exhibited the specimen to the biological section of the British Association at Aberdeen. It consists of a mesial plate about half an inch long, attached along the under border of the terminal part of the cylinder enclosing the notochord and is itself in the recent state covered by a strong fibrous sheath. This cartilaginous plate is of triangular form, having a short vertically-placed concave margin in front, and tapering to a point behind. (Fig. 1.). Its inferior border is slightly convex, and is produced into twenty-four processes or fin-rays. At the anterior inferior angle of the plate is a small bifurcated process expanding into a pair of flattened surfaces directed forwards so as to support or abut against the hindermost pair of mucous glands. I have not been able to trace the caudal artery beyond the margin of the plate; and the accompanying vein, which is greatly enlarged in the two last inches of its course, terminates abruptly, fitting into the concave anterior margin of the plate. The fin-rays are cartilaginous to their extremities, which are easily examined on peeling off the skin, and it can in the same way be seen that there are similar rays in front of them, separate from one another and continued forwards, dwindling in size, as far forwards as the vent, which is situated about two inches from the extremity of the tail. These shorter anterior rays do not project so far as those behind them, and their deep extremities fall a good way short of the sheath enclosing the notochord, being hid between the two rows of close-set mucous glands. The middle of each one is united with those next it by a fibrous band running between the superficial margins of the muscles.

Above the hinder end of the notochord upper caudal rays are placed more closely than the lower caudal, and continued about the same distance forwards. Opposite the sub-caudal plate the upper rays are united at their bases by a continuous strip of cartilage, which may be continued about the same distance forwards as the sub-caudal plate, or not quite so far, but is very narrow, and might well escape attention if not specially looked for. In front of this the upper rays are ununited by cartilage, and are thick and rounded at their bases, which do not approach quite so closely to the neural sheath as does the strip behind them. They are scattered more sparsely further forwards.

All the fin-rays, as also the basal blocks, are composed of cellular cartilage, cartilage-capsules placed closely together without intervening matrix, not unlike the cellular cartilage of the ears of mice and other small mammals (Fig. 2). But it differs in presenting a tendency of the capsules to fall into groups, with the walls which are turned towards other groups a little thicker than those which separate one member of a group from another of the same; and it is difficult to make sure if all the partitions between members of the same group are complete. Each capsule is occupied by a finely granular mass, with a small nucleus. It is a variety of cartilage to which interest attaches on account of its near approach to the structure of notochord; and it strengthens the claim of the notochord to be considered as a modified form of cartilage.

The perichondrium of the fin-rays is strong and fibrous, and exhibits frequent transverse markings, reminding one of the nodes of the rays of osseous fishes. Such nodose rays have an origin in subcutaneous fibrous tissue, not in cartilage. Homologous with them are the horny rays found in great abundance in a number of elasmobranchs, clothing both mesial and lateral fins. A good illustration of the superficial nature of the nodose rays seen in teleosteans may be found in the pectoral fin of a cod, in which the nerves do not run on the surface of the fin-rays, as they would if these rays were of a truly phalangeal description; but they run across the fin, between the upper and lower range of the fin-rays.

From the report of the proceedings of the meeting of the British Association at Aberdeen, it will be seen that I had not at that time discovered the cartilaginous character of the upper caudal rays of myxine, nor suspected the existence of the dorsal plate. It was not till I had dissected the tail of Petromyzon marinus that I began to think it probable that in working with structures imbedded in tough fibrous tissue I had overlooked some which were more delicate than the sub-caudal plate.

In Petromyzon marinus—the large lamprey—the fin-rays consist of opaque yellowish cartilage, which, under the microscope, exhibits rounded capsules, with a small amount of matrix between. They are found in both the dorsal fins as well as in the tail. J. Müller describes cartilaginous rays of the caudal fin "which have their inner cylindrical extremities hidden between the muscles, but not reaching in as far as the column, and with their superficial tapering part stretching out and forming the free fin, bound together by a membrane of connective tissue" (Vergl. Anat. d. Myxinoiden, p. 27). But this statement is not quite accurate for the caudal rays. It is true for the rays of the first dorsal fin, and for the second dorsal as far back as the notch which partially separates it from the caudal continuation, but it is not true for the hindermost inch and a half of Petromyzon marinus, the part behind the dorsal notch, and having about forty superior and as many inferior cartilaginous rays. For in that extent the inferior rays are united at their bases by a continuous cartilaginous bar, nearly a tenth of an inch in breadth, and the superior rays are similarly united by a bar about half that breath. The last superior and inferior rays are parallel above and below the column, and the rays rapidly increase in length as we pass forwards. But in front of the place where the cartilaginous bar ceases, the inferior rays become again rapidly smaller, not being produced so far, nor penetrating by their deep ends so near to the vertebral column.

It will be seen that the tails of Myxine and Petromyzon are really very similar, the main difference depending on the circumstance that the double row of mucous glands, so important a character of the myxinoids, is not developed in Petromyzon, and that, therefore, the button-like supports of the hinder pair of glands, and the abrupt anterior edge of the sub-caudal plate are neither of them found in that genus.

For the rest, the caudal arrangements in both Myxine and Petromyzon are very similar to those of the elasmobranchs. Thus, for example, in Acanthias, Lamna, and Squatina, the superior caudal rays are distinct from both the crural and intercrural* cartilages of the neural canal, just as in Petromyzon they rest above a neural canal in the sides of which somewhat irregular cartilages are developed. In Acanthias and Squatina the inferior rays also resemble those of Petromyzon, being continuous with the hæmal arches, just as in Petromyzon the inferior plate is tunnelled by the vessels. In Lamna, on the contrary, the inferior rays and the hæmal arches are distinct one from the other.

The homological relations of cartilaginous caudal rays to structures further forwards are worthy of note. If we have regard to the laminæ in which the more important skeletal elements are developed, it will be seen that while costal arches appear in the wall of the visceral cavity, and neural arches in the wall of the neural cavity, and both are capable of prolongation in the mesial septa passing downwards and upwards, there is a layer superficial to the muscular mass of the trunk (*i.e.*, to the products

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* I use here the nomenclature of Stannius. Possibly it might be better to speak of neural arches and intercalar cartilages as some have done. But Lamna, one of the forms alluded to, shows a defect common to both sets of names, for in it two orders of cartilages cannot be well distinguished, and we must be content to recognize that the neural cartilages neither corres pond with the vertebral centra nor are multiples of them.

of the embryonic muscular-plates), from which skeletal elements not truly dermal may take their rise. It is from this circle that the centripetal "interspinal" bones of the dorsal and anal fins of teleosteans dip in towards the neural and hæmal spines, and in it that the teleostean clavicle makes its first appearance; and, indeed, it is to the same circle that the whole shoulder-girdle of vertebrates generally belongs, as I have long ago pointed out (Report of British Association, 1869, Sect. proc., p. 120). If we look now at the dorsal fin of Lamna, we find that it has rays quite similar to the upper rays of the tail; but while these latter have their bases resting on the neural arches, and make their way right up between the muscles into the fin, the rays of the dorsal fin have their bases at the surface of the muscular mass, and rest on centripetal cartilages pointing down towards the vertebral column, the first eight of them as simple rods, while the last fifteen exhibit division into a short basal part next the surface and a longer part dipping deeply down, but all of them falling short of the neural canal by a considerable distance. Although, however, the upper caudal rays start from a deeper position than the dorsal fin-rays, they are obviously much more comparable with them than with the centripetal supports of those rays, because both sets of rays pass uninterruptedly from their bases on into the fins. In the dorsal fins of Petromyzon the cartilaginous rays are disposed just as they are in the fore part of the tail, their thick bases placed deeply, and their shafts tapering right on into the fin without regard to the surface of the muscles. On the other hand, the inferior caudal rays of both Petromyzon and Myxine, although even more thoroughly vertebral in origin than the superior rays, are in series, as we have seen, with shorter rays in front of them, which doubtless have originated superficially, and dipped inwards as well as grown out from their origin.

From these complicated relations we may gather distinctly that the same caudal structures may be in series with structures of deep origin and structures of peripheral origin as well. Nor does this arise from mere want of differentiation in caudal regions, for undoubtedly the continuous rays in the dorsal fin of Petromyzon, starting towards the surface from a deep source, correspond with growths which in Lamna commence near the surface and spread both centrifugally and centripetally, namely, the dorsal rays and their supports. The application of these facts to a good deal which is taught by some writers as to the meaning of osseous elements in the turtle, and also elements in the roof of the sturgeon's head, is too obvious, let us hope, to require remark.

As regards plates or bars of cartilage common to a number of fin-rays, it is to be remarked that, although those in the tails of Myxine and Petromyzon are undoubtedly remarkable, they are not without analogy in other fins among the elasmobranchs. Thus the large plate at the base of each dorsal fin in Acanthias is, in the first dorsal, the bearer of three narrower plates, each bearing another surmounted by two nodules, and in the scond dorsal, it is the bearer of two which support three others, each surmounted by a minute addition. So, also, in both dorsals of Squatina and in the anal fin of Lamna, there are plates which belong to more than one ray. In two respects, however, the structures found in Myxine and Petromyzon differ, so far as I know, from anything found in other orders of fishes, namely, that they present a number of simple continuous rays united by a common base, and that these plates, common to a number of rays, are situated in the tail.

EXPLANATION OF PLATE XII.

Fig, 1.—Enlarged view of structures in the tail of *Myxine glutinosa; (a)* upper fin-rays; *(b)* sheath of notochord; *(c)* enlarged caudal vein, fitting at its extremity into the concavity of the sub-caudal plate; *(d)* lower fin-rays.

Fig. 2.—Microscopic texture of the cartilages of the sub-caudal plate of *Myxine glutinosa.*

Fig 3.—Structures in the tail of *Petromyzon marinus; (a)* upper fin-rays; *(b)* neural sheath with irregular cartilaginous nodules in it; *(c)* sheath of notochord; *(d)* lower fin-rays.

XII.

THE ARTERIAL SYSTEM OF VERTEBRATES HOMOLOGICALLY CONSIDERED.

By Dr. J. Yule Mackay.

PLATES XIII., XIV.

In a paper communicated to the *Journal of Anatomy*, January, 1886, Prof. A. Macalister systematises the arrangements of the arteries of man, and draws a comparison between them and a typical arterial scheme founded upon considerations derived from embryology and comparative anatomy. An examination conducted upon such lines provides in many cases a simple explanation of details which, when viewed from the standpoint of human anatomy alone, appear complicated and unintelligible. The development of the arterial system, however, has necessarily been a complicated process, and it is only by the continued accumulation of data that one can hope to understand the relations which subsist between the simple arrangements of lower forms and the highly modified systems of more advanced animals. While agreeing with Prof. Macalister in many cases as to the homological relations of individual arteries, I believe that there is still room for further investigation, and have been led to offer in some instances a different view of development. This is particularly the case in connection with the relations of the branchial arterial arches to the visceral and parietal branches of the longitudinal trunks, and the relations of the branches of the external carotid artery to those of the subclavian and other derivatives of the dorsal longitudinal vessel. I have also added a view of the homologies of the branches of the abdominal and pelvic arteries.

The arteries of a vertebrated animal may be divided into two groups—(1) a primary system consisting of large vessels, and (2) a secondary or branch system passing from the primary to the supply of the body.

The Primary System.

In the early embryonic stage of a vertebrate animal the primary system of vessels consists of the following elements:—(1) Two longitudinal trunks running the whole length of the body upon the dorsal aspect of the alimentary canal; (2) a longitudinal trunk, single at its origin, but rapidly dividing into two upon the ventral aspect of the alimentary canal, passing from the heart towards the head and reaching as far as the mouth, thus occupying only a limited portion of the length of the body; (3) a system of arches upon the right and left sides of the alimentary canal, passing between the ventral trunks and the dorsal trunks. The ventral trunks, although single behind, are probably to be regarded as originally entirely double and belonging each to one lateral half of the body, the single portion being intimately connected in its development with the heart. In many instances the heart has begun to be formed before the splanchnic walls have met and closed, and it arises then as a double structure, fusion being subsequent.

The arches passing from the ventral to the longitudinal trunks are to be found only in the region between the heart and the head. Prof. Macalister believes that in the region between the heart and the tail the arches are represented by a set of arteries passing from the dorsal longitudinal trunks to the supply of the splanchnic wall, and which, breaking up into capillaries and becoming venous, end in the sub-intestinal vein. He regards the sub-intestinal vein as the thoracic and abdominal portions of the ventral longitudinal trunks. This theoretical conception is to be objected to on several grounds. In the neck where the arches are present the splanchnic wall or alimentary canal is supplied by arteries which, while they appear in all respects similar to the arteries which in the abdomen are distributed to the canal, are perfectly distinct from the primary arches. These branches to the alimentary canal in the neck, breaking up into capillaries, end in veins which have no connection with the ventral longitudinal arterial trunks. In fishes and larval amphibians the arches enter the gills, but in all higher forms each, from the very first, consists of a single vessel, and if, as may be done in the chick, their development be watched, they are found to give off no branches whatever to any part of the body. The arches are to be regarded as a system of vessels intermediate in position between those destined for the supply of the splanchnic and those of the somatic walls, possibly in invertebrata forms, represented by a more extended series, but in the vertebrate found only in the region between the heart and the head. (Pl. VII., Fig. III.)

The dorsal longitudinal trunks, running the whole length of the body, fuse, in the region between the heart and the tail, into a median trunk, the aorta, the flow of blood through which is towards the tail. Between the heart and the head, on the other hand, they remain separate in most vertebrates, and form portions of the carotid system, carrying blood to the head.

In the change from the embryonic to the adult stage the relations of these three sets of vessels are considerably modified. The arches vary in number in different forms. In the embryos of all vertebrates higher than the amphibia there are five. They are numbered in order from the head towards the heart. The fifth arches become upon one or both sides solid cords in the adult, stretching to the aorta from the pulmonary arteries, which are given off from the ventral trunk at the commencement of the fifth arches. The fourth arches become upon one or on both sides aortic, according as the adult form has a right or left aortic arch or both. The third arches become portions of the carotid system upon both sides. The first and second disappear.

The ventral longitudinal trunk is divided by an obliquely longi- tudinal septum into two compartments, one of them continuous with the fifth arches, the other with the rest. It forms the basal portions of the pulmonary, aortic, and carotid vessels.

While the dorsal longitudinal trunks in their fused portion between the heart and the tail become the aorta, into which the fourth or aortic arches pass, carrying blood towards the tail, the third arches, carrying blood towards the head, enter them, where they remain separate. The portions upon each side between the entrance of the third and fourth arches, in which the direction of the circulation is indeterminate, become obliterated in many forms and disappear, but they remain open in the lacertilia and stretch between the *common carotid* and the aorta.

The question now arises as to what portion of the carotid system is derived from the dorsal longitudinal trunk between the third arch and the head. Rathke* believed that it was only the internl carotid which was to be regarded as a portion of the dorsal longitudinal trunk, and looked on the external carotid as a portion of the ventral longitudinal trunk; and Macalister, building upon this, describes the branches of the external carotid artery as branches of the ventral longitudinal trunk, and believes, upon theoretical

* Rathke, Archiv. f. Anat. und Physiol., 1843.

grounds, that the posterior auricular and occipital arteries represent incomplete arches stretching from the ventral to the dorsal longitudinal trunk. On the other hand, the subclavian artery is regarded, both by Rathke and Macalister, as a branch of the dorsal longitudinal trunk. In the description of the branches of the primary vessels which follow it will be seen that there is a very marked correspondence between the branches of the subclavian artery and those of the external carotid. Further, branches of these two arteries are directly united to one another, as will be seen, by the anastomotic chains which pass between the branches of the dorsal longitudinal trunk so as to render it exceedingly probable that the branches of the external carotid are to be regarded, like those of the subclavian, as derived from the dorsal longitudinal trunk.

The occipital and the superior thyroid arteries anastomose directly with the deep cervical and inferior thyroid arteries from the subclavian. Macalister looks upon the occipital as one of the primary arches, and if this be so, the superior thyroid ought also to be so reckoned. But Macalister also regards the posterior auricular artery as a primary arch, so that if his theories were true there would be representatives of six arches in the mammal, a larger number than has ever been observed in the embryo of any form higher than the amphibia.

The facts of the comparative anatomy of the external carotid artery render it still more probable that it is to be regarded as a branch of the dorsal and not of the ventral longitudinal trunk. In no case except mammals are the branches of the external carotid artery gathered together into a single root. In all other forms they come off at intervals from a trunk common to them and the internal carotid, and which in many cases (birds and crocodiles) runs for a considerable distance along the dorsal aspect of the alimentary canal before giving off any branches to the head. In lacertilia, in some crocodiles, and occasionally in birds, the portions of the dorsal trunk between the third and fourth arches being present, either as patent vessels or solid cords; in all these forms it is easily seen that the greater portion of the common carotid is dorsal in position, and, consequently, that the external carotid branches are derivatives of a dorsal vessel.

While in non-mammalian vertebrates the external carotid branches, as well as the internal carotid artery, are to be regarded as derivatives of the dorsal longitudinal vessel, it will be seen from the following description of the branch system that whatever opinion may be held as to the dorsal or ventral position of the *basal* portion of the external carotid of mammals, the *branches* of the artery at least correspond to the branches of the dorsal longitudinal vessel.

The Secondary or Branch System.

In studying the branches of the primary trunks it is to be noticed that their arrangement has been modified by the action of two causes. One of these is that in the early embryo the heart is placed close under the head, but in the adult it is removed backwards into the thorax, and the primary arches and portions of the longitudinal trunks to a certain extent participate in the change of position. The chick embryo affords an example. During the fourth day the heart and a portion of the aorta are still in the neck, and the aorta is observed to give off lateral branches to the walls of the neck, but after development is completed and the heart and aorta are found in the thorax, no lateral branches from the aorta pass to the neck. In the descent of the heart and arches the lateral branches from the aorta to the neck have become obliterated. The second modifying cause is the obliteration of the portions of the dorsal longitudinal trunks between the third and fourth arches already alluded to.

Most of the arteries of the body arise from the dorsal longitudinal trunk. A small number take origin from the ventral trunk. None arise from the primary arches. In fishes, where nothing but venous blood passes through the heart, the systematic arteries do not take origin until the blood has become arterialised; that is to say, they are found springing from the vessels beyond the gills, the dorsal longitudinal. In forms higher than fishes, however, where the heart propels both venous and arterial blood, branches are given off from the ventral vessel to a limited portion of the body.

Branches from the Dorsal Primary Trunks: Segmental Branches.—From the dorsal primary trunks branches are given off at intervals corresponding to the segments of the vertebrate body. As it courses through the segment each dorsal trunk may be regarded as giving off branches which pass round the splanchnic and somatic walls to meet in the middle line similar vessels from the other side. Two arterial circles are thus formed, a visceral upon the walls of the alimentary canal, and a parietal upon the body walls. Another set of branches distributed in the embryo to the Wolffian body, and in the adult to structures developed in connection with it, appears to occupy a position intermediate to the two circles; but it seems probable, from the manner in which the Wolffian body is developed, that these arteries are to be regarded as connected more especially with the parietal circle. (Pl. VII., Fig. II.) I have used the word "circle" to denominate the segmental branches of the dorsal longitudinal vessel, in order to avoid confusion between these vessels and the primary arches, which have a similar direction, but occupy a position between the two circles, and are distinct from either. (Pl. VII., Fig. III.)

The visceral circle supplies branches to the alimentary canal and to the organs developed in connection with it. The parietal circle gives branches which radiate from it to the body wall; the most important are (1) a dorsal, (2) a lateral, (3) a ventral. (Fig. II., Pl. VII.)

Longitudinal anastomotic chains connect the circles of successive segments with one another. The most important of these are (1) upon the ventral border; and (2) upon the dorsal border of the alimentary canal; (Pl. VII., Fig. II.); (3) along the ventral aspect of the body wall; (4 and 5) along the ventral and dorsal borders of the neural axis, spinal cord and brain; (6) close to the vertebral column upon the ventral surface of the rib necks; (7) between the rib necks and transverse processes; (8) upon the dorsal aspect of the transverse processes. The last three chains lie in close proximity to one another.

Portions of all the different chains are represented in the human subject. Upon the alimentary canal the two median chains form large vessels on the greater and smaller curvatures of the stomach. Upon the ventral aspect of the body wall the internal mammary and deep epigastric arteries represent a free anastomosis. Upon the neural cylinder the anterior and posterior spinal arteries and the circle of Willis express the anastomotic lines. The three chains which lie close to the vertebræ are but feebly represented in the thoracic and lumbar regions by small vessels, but in the neck they form large arteries—the inferior thyroid, the vertebral, and the deep cervical. In some other forms, however, the last three chains are much more largely developed; in the cetacean class especially, the anastomotic vessels form large plexuses in the thoracic region.

The Visceral Circle.—The following descriptions have special reference to human anatomy. The arteries which pass to the alimentary canal have in most cases lost their segmental arrangement, and their distribution is only to be explained by reference to the exigencies of development. In some cases they will be found springing directly from the primary longitudinal trunk in the middle line, representing, probably in many instances, a fusion of the vessels of the right and left sides. In other cases their origin is literal and conjoined with that of the parietal circle, in which circumstances the vessels of the two sides are distinct.

The interference with the segmental arrangement and the accommodation to developmental processes is well marked in the abdomen. The whole of this portion of the tube is supplied by a series of three arteries, the cœliac axis, and the superior and inferior mesenteric arteries, each distributed, as has been pointed out by Professor Cleland,* to a primary loop of the intestine, and arising directly from the aorta in the middle line. (Pl. VII., Fig. I.) The liver and spleen, organs developed in the mesogastrium, receive their blood supply from the cœliac axis.

The pelvic portion of the alimentary canal receives the middle and inferior hæmorrhoidal vessels from the internal iliac and pudic arteries. In these instances the parietal and visceral circles are conjoined at their bases, and the vessels of the right and left sides are distinct. Vesical arteries also pass from the internal iliac to the urinary bladder, which is developed from a portion of the allantoic diverticulum from the intestine. To the portion of the alimentary canal which is contained in the thorax arteries are supplied in a more regular manner. Œsophageal branches, reduced in number to four or five, and in most cases arising directly from the aorta, enter its coats. The lungs, which are developed as a diverticulum, comparable in many respects to the allantois, receive their blood by bronchial arteries, either directly from the aorta, as upon the left side, or from the parietal circle formed by an intercostal artery, as upon the right side.

To the alimentary canal in the neck, the sources of the blood supply have been modified by the combined action of the two causes already noted; the descent of the whole system of vessels into the thorax, obliterating the segmental branches which, in the embryonic stage, spring from the aorta in the neck, and the disappearance of the dorsal longitudinal vessel between the third

* Cleland, *Journal of Anatomy*, iv., 1870.

and fourth primary arches. Under these circumstances, the blood supply to this portion of the intestine is maintained by the enlargement of one of the anastomotic chains. The inferior thyroid artery represents the continuation upwards into the neck of the anastomotic chain between the segmental branches which lies upon the anterior surface of the rib necks. The artery from which it rises —the subclavian—is to be regarded, probably, as representing a fusion of the parietal and visceral circles of two or more segments. The other branches to the alimentary canal spring from the external carotid artery, when that trunk exists, namely, in mammals; they are the superior thyroid, lingual, ascending pharyngeal, and branches from the facial artery. The superior thyroid artery is the continuation downwards from the external carotid of the same anastomotic chain, which continued upwards from the subclavian formed the inferior thyroid artery. The lingual and the ascending pharyngeal represent the visceral circles of still higher segments, while the facial artery supplying visceral and parietal branches is probably to be regarded, like the pudic, and, like the external carotid itself, as representing a basal fusion of the visceral and parietal circles.

The Parietal Circles.—The parietal circles have been least interfered with in the thoracic and lumbar regions, where they form the intercostal and lumbar arteries. These vessels course round the body wall and unite with the anastomotic chains formed by the internal mammary and epigastric arteries. The radiating branches are the dorsal, the lateral, and the anterior. The dorsal branches send twigs into the spinal canal to supply the neural axis, the lateral branches ramify in the body wall, and are in series with the arteries which in the pectoral and pelvic regions enter the limbs.

At the lower end of the abdomen, while the dorsal longitudinal trunk is continued onwards as the middle sacral artery, the parietal and visceral circles, have become fused on each side into one stem—the common iliac artery. The visceral circles have been already noticed. There are five distinct parietal circles—the external iliac, the obturator, the gluteal, the sciatic, and the pudic. The external iliac artery is continued round the body wall, its terminal branch joining the ventral anastomosis formed by the epigastric artery. The lateral branch of the external iliac forms in mammals the femoral artery, and supplies the pelvic limb. The obturator artery passess round the somatic wall, and is joined by anastomotic branches to the epigastric artery; in instances where the root of the obturator artery fails, it arises from the epigastric by a further prolongation downwards of the ventral anastomotic chain. Lateral branches of the sciatic artery are prolonged for some distance with the nerves; and in birds and reptiles these form the main supply of the limb.

At the upper end of the thorax, the subclavian artery represents a fusion, probably, of the visceral and parietal circles of the last cervical and first thoracic segments. The parietal branches sweeping round the body wall terminate in the ventral anastomotic chain as the root of the internal mammary and the first intercostal artery. One lateral branch is prolonged as the axillary artery into the limb, and others are represented by the tranverse cervical and supra-scapular.

In the neck, owing to the obliteration of the dorsal longitudinal vessel, the origin of the segmental circles is transferred to the longitudinal anastomotic chains. Three of these are present connected below with the subclavian and above with the carotid artery. They are the inferior thyroid joining the superior thyroid, the vertebral joining the internal carotid, and the deep cervical joining the occipital. (Pl. VII., Fig. I.)

The external carotid artery may probably be regarded as a stem of secondary formation, uniting the origins of visceral and parietal circles of several segments. This view is corroborated by the consideration that the external carotid trunk is peculiar to mammals. Among the parietal branches the occipital, continued into anastomosis with the chain which lies on the dorsal aspect of the transverse processes, is to be regarded as dorsal. The internal carotid, after leaving the neck, corresponds to an enlarged spinal branch.

The Intermediate Arteries.—The vessels which, springing from the abdominal aorta, supply the Wolffian body and its derivative organs may be so termed. They are the supra-renal, the renal, and the spermatic or ovarian. Probably in the pelvis the uterine and vaginal have a similar origin. These vessels join in a subperitoneal anastomosis with the branches of the parietal circle.

Branches of the Ventral Longitudinal Trunk.—If the branches of the external carotid artery be considered as belonging to the dorsal trunk, the branches of the ventral trunk are few in number. They are represented by the pulmonary arteries, the coronary arteries of the heart, and the occasional thyroidea ima. In some mammals, as the cetacean group, the thyroidea ima is constant. In forms lower than mammals the branches from the ventral trunk are large and important. They are described along with the comparative anatomy of the subclavian artery in the next section.

Comparative Anatomy of the Anastomotic Chains between the Subclavian and Carotid Arteries.

The subclavian artery, although in mammals springing from the dorsal longitudinal vessel, is yet in some other forms a branch of the ventral longitudinal trunk. This second mode of origin is to be found in birds and in crocodilian and chelonian reptiles—in which groups ~~of~~ the subclavian is found to stretch outwards to the limbs, from the ventral margin of the base of the carotid stem, crossing in its course, superficial or ventral, to the pneumogastric nerve and jugular vein. There are thus two vessels which, in different circumstances, may be prolonged into the pectorial limb—one from the dorsal trunk found in most mammals, in lacertilian reptiles, and in amphibians, the other from the ventral vessel in birds and crocodilian and chelonian reptiles. In most cases both these arteries are to be found co-existing, although but one reaches the limb. Among mammals, in the porpoise and in other cetacean animals, it is the artery from the ventral trunk which supplies the limb, but the artery from the dorsal trunk is present as a very large vessel—the posterior thoracic—distributing its branches chiefly to the great thoracic arterial rete, but also giving off branches to the neck, which correspond to the inferior thyroid and deep cervical of the human subclavian. In lizards both vessels are present, but, as in the human subject, it is the dorsal one which is prolonged into the limb, the ventral one losing itself in branches among the scapular muscles. It is important to notice that in all cases where the two arteries are to be found they anastomose freely with one another in the lateral body wall. The comparative anatomy of the subclavian artery may thus be briefly summarised :—There are two vessels, one arises from the ventral longitudinal trunk, and runs round the body wall in a dorsal direction, the other arises from the dorsal trunk and runs round the body wall in a ventral direction ; they anastomose in the body wall, and at the place of anastomosis the branch to the limb arises. (Pl. VII., Fig. III.) In most cases both roots are present, one or other being the larger. On account of the free anastomosis in the lateral wall, when one root is very much reduced in size, some of its more external branches may be transferred to the other.

The branches specially belonging to the ventral root are, compared with those of the dorsal root. unimportant. From its inner end an artery corresponding to the thyroidea ima of human anatomy is supplied to the trachea and œsophagus. In amphibians and lacertilian reptiles this artery is prolonged to the tongue, but, in the successively higher stages it is reduced in size, until finally, as in most mammals, it disappears altogether. Other branches from the ventral subclavian are (2) a connection with the internal mammary upon the ventral aspect of the body wall, and (3) a branch to the dorso-lateral aspect of the neck anastomosing with arteries from the dorsal root and from the carotid. From the dorsal root of the subclavian artery the three anastomotic chains already noticed are continued into the neck. In the different groups of vertebrates much variation is found in respect of the apparent origin and relative development of these three vessels, but in every case an explanation may be found by an application of the principles already laid down.

In the amphibia, in which the subclavian takes origin by its dorsal root, after the manner of the mammalian artery, only one of the three anastomotic chains is enlarged and prolonged into the neck. A vessel corresponding to the deep cervical artery passes to the head among the dorsal muscles of the neck. This vessel should anastomose with an occipital artery from the carotid, but no such vessel being present, the deep servical of the subclavian is itself continued forwards to the back of the head as an occipital artery. The origin of an occipital artery from the subclavian is easily explained by reference to the anastomotic chain, but it is rare to find the root from the carotid absent altogether. A very similar state of parts, however, is found among mammals in the cetacean group.*

In the chamaeleonidæ among the reptiles, while, as in the amphibia, only one of the three anastomotic chains is specially enlarged, the vessel which corresponds to the inferior thyroid artery of mammals plays the important part. The subclavian arises by its dorsal root and gives off, close to its origin, a vessel—

* Arterial System of Porpoise. *Proceedings* of the Philosophical Society of Glasgow, 1886.

the ascending cervical—which passes forwards nearly to the base of the skull below the cervical transverse processes, and detaches twigs to the œsophagus, the subvertebral muscles, the spinal cord, and the dorsal muscles of the neck.

Among the chelonian reptiles a complication is met with. The subclavian arises by its ventral root and passes round the body wall in a dorsal direction. The dorsal root and some of the intercostal arteries behind it have disappeared, but the circulation is maintained from the ventral vessel by the anastomosis in the lateral body wall. The ventral vessel is therefore continued right round the body wall and terminates in the longitudinal anastomotic chains which appear to be continued forwards to the head and backwards towards the tail from a ventral subclavian artery. Of the three anastomotic chains prolonged into the neck, only one is specially enlarged. This vessel corresponds to the deep cervical of human anatomy and runs forwards among the dorsal muscles of the neck to terminate in anastomosis with the occipital artery from the carotid.

Among the crocodilian reptiles further complications are met with. The subclavian arises by its ventral root, the dorsal root being very much reduced in size. The ventral subclavian, as in the chelonian passes right round the body wall into the longitudinal anastomotic chains. Here, as in the other forms, only one of the three lines is specially enlarged, and in this case it is that between the rib necks and transverse processes, corresponding to the human vertebral artery. The first parietal circle which arises from the aorta is supplied to one of the lower intercostal spaces, but an anastomotic chain passes forwards from it, supplying the spaces in front. This is continued into the neck as the vertebral artery, but it is reinforced at the anterior end of the thorax by a branch from the subclavian, corresponding to the root of the deep cervical artery in the chelonian reptiles, while in the neck the vertebral artery receives a third root from the carotid portion of the dorsal longitudinal vessel, which in crocodiles and in birds runs forward for a considerable distance close to the middle line before dividing into its external and internal branches. In the crocodile the anastomotic chain which forms the vertebral artery is thus entered by three different roots.

The manner in which the vertebral artery of the crocodile terminates is interesting. It is the only one of the three anastomotic chains, which is specially enlarged, and in the thoracic portion of its course it gives off a number of intercostal or parietal arteries. In the neck these are still given off, although much reduced in size, and immediately behind the skull it ends in a double manner. Its larger portion, like the dorsal branch of a parietal artery, terminates in anastomosis with the occipital artery, resembling in this respect the human deep cervical, while by far the smaller portion, after the manner of the spinal branch of a parietal artery, passes on to the neural axis to anastomose with the internal branch of the carotid artery like the human vertebral.

In birds, as in all the other forms yet considered, only one of the three anastomotic chains is specially enlarged, and, as in crocodilian reptiles, it is the vertebral artery which is prolonged into the neck. The subclavian artery arises by its ventral root, and, as in the crocodile, the vertebral artery should take origin by roots from three distinct places, but of these two are so reduced in size as to appear absent. The main root is that from the carotid artery, or, in other words, from the carotid portion of the dorsal longitudinal vessel. Of the other roots, that from the first aortic intercostal artery is represented by a fine anastomotic thread between the two vessels, while that from the ventral subclavian continued round the body wall into the anastomotic chain is not to be found. In a number of dissections, made for the purpose of tracing the connection between the subclavian and vertebral arteries, while I was able to follow their branches into close proximity to one another, I could not demonstrate actual anastomosis. The vertebral artery of birds terminates, like that of the crocodile, in a double manner, the larger portion inosculating with the occipital, the smaller with the internal carotid artery.

In mammals, in which the subclavian arises by its dorsal root, the type followed is that of the human subject, in which, as has already been explained, the three anastomotic chains are represented. The cetacean class forms an exception. Here both ventral and dorsal roots are present, the branches to the limb passing from the ventral vessel. From the dorsal vessel, however, two anastomotic chains pass into the neck, corresponding respectively to the inferior thyroid and deep cervical of the human subject, the vertebral being unrepresented.

There are many varieties in the different groups of mammals in the origin of the vertebral artery, but in most cases it arises either directly from the subclavian, or from the aorta in its immediate vicinity. In the human subject, too, while the vessel normally takes origin from the subclavian, it is sometimes found springing from the aortic arch. A very interesting relation of parts is exhibited in a preparation of the arteries of the hooded seal *(Stemmatopus cristatus)* in Professor Cleland's Museum. The vertebral artery (Pl. VIII.) in this animal, while arising from the subclavian, is reinforced by a considerable longitudinal anastomotic chain lying between transverse processes and necks of ribs, and springing from a trunk common to the first and second aortic intercostal arteries. These relations call to mind the anatomy of the vertebral artery in the crocodile, but there is this difference to be noted, namely, the subclavian artery of the seal is dorsal, that of the crocodile is ventral in origin.

In the human subject Mr. A. M. Paterson* has described a vertebral artery arising, not from the subclavian, but abnormally from the first aortic intercostal artery. Such a case as this is obviously to be explained by the failure of the branch from the subclavian artery to the vertebral anastomotic chain, which in the circumstances has had to depend for its supply of blood upon the next parietal circle—the first aortic intercostal.

DESCRIPTION OF PLATES.

Plate VII., Fig. I.

I., II., III., IV., V.—The primary arches. Between I. and V., the ventral longitudinal trunk.

Ao.	Aorta.	*C.c.*	Common carotid.

Branches of the dorsal longitudinal trunk.

I.c.	Internal carotid.	*1,2,3.*	anastomotic chains.
occ.	occipital.	*c.a.*	cœliac axis.
l.	lingual.	*s.m.*	superior mesenteric.
f.	facial.	*i.m.*	inferior mesenteric.
s.th.	superior thyroid.	*e.i.*	external iliac.
s.	subclavian.	*o.b.*	obturator.
i.th.	inferior thyroid.	*gl.*	gluteal.
v.	vertebral.	*s.c.*	sciatic.
d.c.	deep cervical.	*pu.*	pudic.
in.	intercostal.	*h.*	hæmorrhoidal.

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* Paterson, *Journal of Anatomy*, No. xviii., 1883-84.

Fig. II.

v.c. visceral circle.
p.c. parietal circle.
x. intermediate arteries.
l. lateral branch.
a. dorsal anastomosis on alimentary canal.
b. ventral anastomosis on alimentary canal.
c. ventral anastomosis on body wall.
d. dorsal anastomosis on neural cylinder.
e. ventral anastomosis on neural cylinder.
f. anastomotic chain, dorsal to transverse processes.
g. anastomotic chain between rib necks and transverse processes.
h. anastomotic chain, ventral to transverse processes.

Fig. III.

d.t. dorsal trunk.
v.t. ventral trunk.
v.c. visceral circle.
p.c. parietal circle from dorsal and ventral trunks.
p.a. primary arch.
l. lateral branches.

Plate VIII.

Arteries of Hooded Seal *(Stemmatopus cristatus).*

Ao. Aorta.
In. Innominate.
C. Common carotid.
S. Subclavian.
Cer. Cervical branch of subclavian.
Ax. Axillary.
I.m. Internal mammary.
V. Vertebral.
Int. 1. 1st aortic intercostal.
Int. 2. 2nd ,, ,,
Int. 3. 3rd ,, ,,
Between Int. 1 and V.—Anastomotic chain between vertebral and first aortic intercostal.
Cor. Coronary artery.
Œs. Œsophagual branch.

XIII.

TERATOLOGY, SPECULATIVE AND CAUSAL, AND THE CLASSIFICATION OF ANOMALIES.

By Professor Cleland.

If the advantage which biological doctrine has hitherto derived from teratology has not been great, the reason has lain, not in the barrenness of the teratological field, but in the small amount of progress made in determining the true nature of teratological phenomena. Even after the old conception of *lusus naturæ* had been thrown aside, the most imperfect notions continued to prevail both with regard to abnormalities by excess and many of the more important abnormalities by defect. But we have now arrived at a time when no thoughtful inquirer can be longer content with merely cataloguing deviations and bestowing on them sesquipedalian names such as were perhaps justifiable in the days of the elder St. Hilaire. Investigation has entered on a more strictly causal stage, and, to my thinking, it becomes evident that teratology has an important work before it in relation to biological science generally, by demonstrating the presence of potentialities which in the normal organism remain latent, but nevertheless must exist, or they could not in exceptional circumstances show their presence.

Just as in atavism the progeny reveals what was latent in the parent, so in monstrosities, potentialities of growth are revealed which never come to the surface in the ordinary course of development, but yet must exist in normal circumstances, otherwise they could not show themselves when exceptional conditions occur. The cyclopian nose and the intermaxillaries found in cases of completely cleft palate afford illustration of this. So also the occasional occurrence of more or less complete fissiparous division of the embryo is the only evidence we have, and it is ample evidence, that there is in the embryo an inherent possibility of fissiparous division capable of being excited to action, as the labours of Dareste abundantly show, by irritation from without.

In like manner a careful study and collation of the varieties of multiplication of digits will lay bare the mode of action, in exceptional circumstances, of powers of growth ordinarily altogether hid, and may possibly throw light on the nature and seat of the powers by which the normal digits are developed. I have gone even further, and in a previous article ("On Birds with Supernumerary Legs"), have arrived from teratological data at such generalizations as that every vertebrate animal has at an early period a latent capability of splitting up indefinitely; that there are factors at work in development which are not resident in the individual chemical molecules nor even in the individual nucleated corpuscles; and that the moulding powers of two individualities may be at work in areæ overlapping one another, that is to say, may exhibit their influence on one mass of tissue by organs of the two individualities being developed, mutually included each within the territory of the other.

The future of teratology in relation to the larger biological problems promises great things. But to attain them it is necessary that the study should advance within its own limits and proceed from mere phenomenology to causation; and it is only by degrees that we can expect to lay bare the causes of phenomena so complex. Yet as the operations of causes unfold themselves, questions become simplified, in as much as appearances very diverse are often found to be allied. Thus, I have elsewhere pointed out in general terms how closely related are anencephalus, encephalocele, and cyclopia, all of them being results of overstimulation of the more superficial parts already laid down in the young embryo, and depending for their peculiarities on the precise extent and date of the stimulation; and have further given reasons for believing that such overstimulation, when it occurs soon after impregnation of the ovum, leads to fissiparous division of the germinal mass, resulting in two embryos; that at a later period, or carried to a slighter extent, it will cause partial division resulting in such forms of double monster as have a portion of the cerebro-spinal axis undivided; that at a still later period, when the cephalic end of the neural furrow is formed but is still open, it produces thickening and irregular folding of the cerebro-spinal axis such as effectually prevent its assumption of the cylindrical form; that anencephalus is produced by rupture after the primary optic vesicles are cut off from the cerebral vesicles; that lumbar spina bifida is occasioned at a later date; and that cyclopia also is probably of later origin than anencephalus ("On Spina bifida, &c.," *Jour. Anat. and Phys.*, XVII., 257).

Now, after many years consideration of double monsters, I begin to see with some measure of clearness how the varieties and degrees of duplicity are attributable to such circumstances as the following:—

1. The period of application of the excitant to division.

2. The amount of excitation.

3. The interference of the adjacent parts of more or less completely divided embryos, each with the growth of the other.

4. The equal or unequal development of the two embryos produced on one ovum, or of the doubled portions of a partially divided embryo.

5. The commencement of fission at the caudal or cranial end of the embryo, or at both ends.

6. The operation of the law by which symmetrical parts tend to adhere one to the other. Of this law of symmetrical adhesion it is to be remarked that, while advocates of the exploded theory of double monstrosity by adhesion of embryos from distinct ova were in error in imagining bifurcating of embryos to be instances of the operation of the tendency of corresponding parts to become united, the law nevertheless exists and shows itself in two ways—namely, the junction of corresponding right and left parts of one embryo, as in the normal closure of the body-cavity; secondly, the junction of the parts on the right side of a right embryo with the corresponding parts on the left side of a left embryo; while a third phenomenon is noticeable, which is liable to be confused with the law of symmetrical adhesion—namely, the union of parts on the left side of a right embryo with corresponding parts on the right side of a left embryo. Phenomena of this last description I have largely referred to in speaking of supernumerary legs of birds; they are, however, not so much examples of adhesion of previously distinct parts, as rather examples of non-separation of parts; and this distinction shows itself in the circumstance that by symmetrical adhesion the parts abutting on the middle line are united but never suppressed, whereas extensive suppression often occurs in the line of contact of the adjacent sides of right and left embryos. Thus a composite limb is often formed between the adjacent sides of a right and left embryo, but never between the further sides which come round to meet one another in front; and, indeed, if this had been appreciated before now, it would

not have been left to me to explain the nature of subcaudal supernumerary legs in birds.

Influenced by considerations such as the foregoing, I have attempted to frame a system of classification of anomalies which will introduce, to a greater extent than has been done heretofore, the element of causation; and although the result is admittedly imperfect, I bring it forward in outline, in hopes that it may be found useful. Such an attempt, imperfect though it must necessarily be, will have its use in laying out to observers the task of determining more explicitly than might otherwise occur to them, the nature of the early changes leading to any anomaly, and the antecedents which have led to those changes.

I have found it advisable to continue the practice of primarily dividing anomalies into those by defect and those by excess, notwithstanding that I have had occasion to point out the extraordinary fact that the same cause which at one date may lead to double monster may at a somewhat later period lead to varieties of anomaly by defect. For among the deformities resulting from external irritation, the differences determining whether the irritation shall excite the embryonic mass to division, or only its individual corpuscles to altered nutrition, are really of primary importance; while those anomalies which cannot be distinctly referred to external irritation, so far from constituting a homogeneous group, are rather a temporary accumulation bound together by the accident that we cannot as yet determine their cause.

Among such unexplained anomalies there stand out prominently those exhibiting excessive or defective size, imperfection of form, or sexual deviation. With regard to amount of growth, we have abundant example in the vegetable kingdom of how it may be fostered or retarded by surrounding circumstances, and yet is subject to the internal influence of heredity. Thus, a good stock in a bad soil will produce a better result than a bad stock in the same, while any given stock will produce more favourable results, the more favourable the soil. As for imperfection of form, it may indeed be conceived as resulting in some instances from defective transmission of the hereditary quality by which organisation is carried on, but certainly in some cases it is the effect of the interference of adverse circumstances with the action of the hereditary quality, and it is not easy to say in how many it may be so.

But of all anomalies not distinctly referable to external causes, sexual anomalies are the most remarkable. There may be failure of development of sexual organs without any apparent mechanical cause; unusual growth in male or female of organs properly pertaining in their full development to the opposite sex; or, more rarely, the essential organs may be partly male and partly female, as has been described as occurring in the herring. But in the absence of all definite information as to the causes which determine sex, there seems at present no likelihood of being able to trace how far such anomalies are dependent on external, how far on hereditary causes. There is therefore only the slightest allusion made to them in the following tabulation. Let it, however, be distinctly understood that true hermaphrodism, the formation of both ova and spermatozoa in one individual, is neither anomaly by defect nor by excess, but is altogether *sui generis.* Such a phenomenon might possibly occur in the human subject; but it has never been observed, so far as I know.

TABULATION OF MONSTROUS AND ANOMALOUS FORMS.

I. BY DEFECT *(exclusive of acephali and acormi.)*

A. Without distinct external cause.

1. Dwarfing, *a*, of the whole body; *b*, of portions.
2. Failure of completion of form of parts. Among the most notable of these may be mentioned—harelip, single and double; cleft palate; open lachrymal fissure; openings below the ears; cleft sternum; imperfect reproductive organs; certain cases of ectopia viscerum and ectopia vesicæ (?); certain cases of imperforate anus; deficiency in number of digits.

It may be remarked that it is perfectly possible that not one of those local defects is ever altogether dependent on mere want of hereditary impulse, but, on the other hand, it is most important to face the difficulty of determining the exact causes of them, if we are to get information on the subject. In the case of ectopia viscerum, ectopia vesicæ, and imperforate anus, it would, no doubt, be practically inconvenient to break up each into widely separate groups, while the exact position of a number of varieties would be left undetermined; but it is nevertheless important to recognise that while it is certain that they all are most frequently the result of local irritations there are yet instances of which it is difficult to say how they have arisen.

B. Consequent on dropsies and changes connected therewith.

1. Pleuro-peritoneal. Probably many cases of ectopia viscerum.
2. Cerebro-spinal.
   - *a.* Part or whole of the central canal of the spinal cord—spina bifida.*
   - *b.* Part or whole of the cerebral ventricles—anencephalus, cyclopia, hernia cerebri in its different varieties.

C. By Strangulation.

1. From thickened tissue occluding openings or preventing their formation.
   - *a.* Imperfections of middle and external ears.
   - *b.* Obstructions of buccal opening, leading to swelling of the pharynx and agnathia.
   - *c.* Obstruction of urethra, leading to ectopia vesicæ and epispadias.
   - *d.* Obstruction of vent, leading to imperforate anus.

There are instances of imperforate anus in which the coats of the rectum are gathered to a spot behind the prostate and the mucous membrane to a pit there, as if it had been within the grasp of a constriction, and these are the cases referred to.

2. From obstruction to the separation and expansion of potential parts.
   - *a.* Lateral organs may be bound together so as to remain united in the middle line, while the mesial structure which ought to have intervened, and the most closely crushed parts of their own structure are suppressed. There can be little doubt that such malformations are to be attributed to tissue of increased density strangling the node of growth of the mesial structures and tying down the lateral parts. This seems to be the case in the cyclopian eye and the cyclopian proboscis. I should think that sympodia is to be explained in the same way.

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* It is unnecessary to discuss here the varieties of spina bifida with the many disputable points as to their causation, but I may refer to the article which I have contributed to Dr. Morton's work, "The Treatment of Spina Bifida by a New Method." Second edition, 1887.

b. Lateral organs may be directly strangled. This seems to be the most likely explanation of some cases of shortening of the limbs, and of some intra-uterine amputations.

3. From external causes.
   a. Strangulation by umbilical cord.
   b. Strangulation by fibrin in the liquor amnii.

It may be here remarked that deficiency of limbs certainly depends on at least three different causes. Montgomery figures from Zagorsky a minute foot hanging by a fibrinous thread which has also cut its way considerably into the other leg, and this seems to prove that amputation may be effected by means of fibrinous threads. He further figures a fœtus in which amputation of a thigh is threatened from constriction by the umbilical cord; and it is obvious that neither of these explanations will account for symmetrical absence of all the limbs. But cutaneous affections in adults are often symmetrical, and it seems quite possible that superficial thickening might occur in all four limbs so as to involve the tissue from which their distal parts are developed. Further, it is obvious that the same process which in one instance involves the whole centre of growth for the distal parts of a limb may in another produce a mere annular constriction beyond which growth may proceed without interruption. I have a curious specimen of a leg taken from a fœtus which had a number of constrictions and baggings of the integument. The tibia has been cut right through a little below the knee, and has a special pouch of integument, while the foot though turned inwards is otherwise normal, and the fibula is enlarged inferiorly, but there is no vestige of the lower part of the tibia. This looks as if the strangulation which cut free the upper part of the shaft had embraced the rest of the tibia in its whole length when it was still minute in size.

II. BY EXCESS.

A. Hypertrophy.

1. Of the whole body—Giants.
2. Of parts, e.g., digits or epidermal appendages; also of sexual or other accessary reproductive organs.

B. Multiplication of parts—Polydactylism.

C. Longitudinal fission of embryonic mass.

1. Complete fission.

A. Permanent—twins in one chorion.

B. Temporary—the divisions subsequently united by corresponding parts. These are double-monsters having, common to both divisions, no portion of column nor cranial base such as might belong to a single fœtus.

(*1*) Union confined to the neighbourhood of a common umbilicus, *e.g.*, the Siamese twins.

(*2*) Union from umbilicus upwards to form one thoracic cavity.

(*3*) One thoracic cavity and the heads also united (*a*) with two complete faces, the half of each belonging to each body—Janiceps; (*b*) with the hinder face and adjacent portions of crania undeveloped from want of room.

(*4*) Union of cranial vaults of two fœtuses, otherwise distinct, and having two umbilici.

(*5*) Union pelvic, heads at opposite ends, legs and genitals thrown to the sides.

2. Incomplete fission.

A. Abcaudal.

(*1*) The divisions equally developed, one head and two bodies.

(*a*) Adjacent upper limbs distinct.

(*b*) Adjacent upper limbs blended together.

(*2*) One division altogether larger than the other; the larger continuous with the head and upper part of the column; the connections of the smaller division defective.

(*a*) Smaller division appended to the thorax or abdomen, and exhibiting a pair of lower limbs with variable amount of body and sometimes a pair of upper limbs, while its thoracic viscera may be contained within the thorax of the developed individual. Lalloo, a Hindu, 18 years of age, at present alive, is a good example.

(*b*) Smaller division included within the other. Three such cases are on record, published by G. W. Young, Dupuytren, and N. Highmore.

(*c*) Smaller division completely separated from the continuous fœtus and forming an acephalus. (See p. 7 of this volume.)

(*3*) One division of the trunk disappears altogether, and the right and left pelvic limbs of the right and left divisions respectively are completely developed, while the left pelvic limb of the right division and the adjacent right pelvic limb of the left division are dwarfed and more or less blended (*a*) with partial visceral duplicity; (*b*) without any visceral duplicity. To this group belong limbs appended to the perinæum, and amorphous tumours attached to the sacrum. (See foregoing Memoir on Birds with Supernumerary Legs.)

(*4*) One division of the trunk almost completely disappears, and the adjacent lower limbs of the two divisions completely disappear. (See Memorandum 4, "Spina Bifida with Bony Projections into the Spinal Canal.")

B. Abcranial.

(*1*) The divisions equally developed.

(*a*) Duplicity in front of the occipital bone.

(*b*) Complete duplicity of the head and part of the spinal column.

(*2*) One division larger than the other.

(*a*) The smaller division appended in front, and consisting of the head, limbs, and part of the body, *e.g.*, Lazarus Colloredo.

(*b*) The smaller division broken off as an acormus.

(*3*) The axial parts of one division of the bifurcated embryo entirely disappears, the right pectoral limb of the right division and the left pectoral limb of the left division being developed as normal limbs, while the adjacent pectoral limbs of the two divisions form an appendage connected with the cervical vertebræ. (See Memorandum 5, "Appended Fore-Limbs.")

C. Fission simultaneously abcaudal and abcranial. The essential feature is that while some part of the spinal cord and column is single, there is duplicity both above and below. An example exists in the negresses exhibited as the "Two-headed Nightingale."

It is not pretended that this tabulation of anomalies is thoroughly exhaustive, nor that all its speculations must necessarily be perfectly correct, but I venture to think that it opens up a path of investigation calculated to advance science and to help to gain for teratology the place which I have claimed for it in the commencement of these remarks.

XIV.

CASES OF ABNORMALITY OF THE ARTERIES OF THE UPPER LIMB.

BY JOHN YULE MACKAY, M.D.

PLATE XV., Figs. 1 and 2.

THE following cases, which have been selected from the records of a large number of subjects in which the arteries of the arm departed from the usual arrangement, demonstrate the inaptitude of the present system of nomenclature of the abnormal vessels. They suggest also the methods by which in certain circumstances these vessels arise.

(1.) In both arms of a male subject, dissected in the winter of 1887, the arteries were found to be disposed in an abnormal manner. In the left arm, which presented the simpler arrangement, the axillary artery (Fig. 2, Plate XV.) divided immediately above the tendon of the teres major muscle into two trunks which were continued through the arm. Near the forearm one of these trunks divided into radial and ulnar arteries, while the other passed on to distribution as the common interosseous artery. According to the accepted system of nomenclature the first of these vessels is to be regarded as the "true brachial artery," and the second as a "high interosseous artery."

The first (the so-called true brachial artery), the smaller of the two, passed down the upper arm, running along the inner margin of the biceps muscle, in front of the median nerve, and gave off in its course merely a few slender branches to the biceps. At the lower end of the upper arm it deviated a little to the inner side, and divided about half-an-inch above the level of the elbow joint into radial and ulnar arteries. Of these derivative trunks the ulnar passed almost directly downwards, with a slight inclination inwards, lying in its course superficial to the muscles but underneath the investing fascia, and did not gain its usual position until the lower fourth of the forearm had been reached. In the upper three-fourths of its course the only branches derived from the ulnar were slender twigs distributed to the muscles upon which the vessel lay. The radial artery was directed downwards and outwards upon the surface of the pronator radii teres muscle, and like the ulnar did not gain its usual position until the lower fourth of the forearm, distributing in the upper part of its course only slender muscular branches. In the lower fourth of the forearm and in the hand the radial and ulnar arteries occupied their normal positions and were distributed in the usual manner.

The second and larger trunk arising from the axillary artery (the so-called high interosseous) was placed in the arm behind the first vessel and entered the hollow in front of the elbow in the position which the brachial artery occupies in normal circumstances. The only deviation from the position of a normal brachial artery which this vessel presented was a slight convexity inwards as it lay upon the brachialis anticus muscle. It showed also the relations to the median nerve characteristic of the lower portion of the axillary and of the normal brachial. The inner head of the nerve crossed it. In the upper portion of the arm the nerve lay along its outer side, and still further down crossed the vessel and passed into the forearm by its inner margin. The nerve was also bent slightly inwards in the lower part of the upper arm. The branches given off were also significant. They were—the subscapular, posterior circumflex, superior profunda, inferior profunda, anastomotic, and muscular. In the forearm the artery divided at the upper end of the interosseous membrane, but before so doing the radial recurrent and the anterior and posterior ulnar recurrents were detached. From the anterior interosseous artery there arose an enlarged median artery which entered the hand with the nerve and inosculated with the superficial palmar arch.

From the foregoing details it is evident that the vessel last described, the so-called high interosseous artery, corresponds in position, relations, and distribution in the upper arm to the brachial artery of normal circumstances, and it is evidently the direct continuation of the axillary trunk. In the forearm also it represents a large number of the branches which normally spring from the derivatives of the main vessel. On the other hand, the vessel first described, the so-called true brachial, shows in no part of its course in the axilla or upper arm either the position or relations of the trunk which normally supplies the limbs, and in respect of branches distributes only a few, and these belonging entirely to the set which ramify in the biceps muscle. In the greater part of the forearm also the derivative trunks (radial and ulnar) are abnormal in position and relations, and distribute only muscular branches. Such a trunk as this would seem to be developed as a collateral stem (single above where it arises from the axillary, and double below where it joins the lower ends of the radial and ulnar), out of anastomotic branches distributed to the biceps and to the muscles of the forearm; and the system of nomenclature which permits of its being denominated the true brachial artery is obviously an artificial one.

The opinion above expressed is confirmed by an examination of the relations of the vessels in the right arm. In almost all particulars the abnormal details were the same upon both sides, and they were evidently due to a similar cause; but a trivial difference in arrangement gives the abnormality upon the right side, according to the present system of nomenclature, a very different designation.

On the right side (Fig. 1, Plate XV.) the axillary artery divided into two trunks, which, in the axilla and in the upper arm, were precisely similar to those already described on the left. In the forearm also the relations were generally similar to those on the left, with this difference, however, that the radial artery was, in the hollow of the elbow and about an inch below its origin, united into one common stem of about $\frac{1}{8}$th of an inch in length with the vessel which upon the left side was designated "high interosseous." As a less important difference it was noted that the enlarged median of the left side was only represented on the right in its lower part, by a recurrent branch from the superficial palmar arch. By virtue of this complication on the right side of a short junction between the vessels which upon the left were designated "radial" and "high interosseous," the whole nomenclature of the abnormality is altered, though the vessels themselves are identical. In this arm the abnormality has to be described as a high ulnar artery, arising from the axillary and united by a trunk of about an inch in length (corresponding to the first portion of the radial of the other side) with the main vessel in the hollow of the elbow.

The vessel which upon the left side was called "high interosseous" is on this side the "true brachial," while the so-called "true brachial" of the left is the "high ulnar" of the right.

With regard to the ætiology of the abnormal conditions, it was noted upon the right side that the main vessel was, along with the median nerve, bound down by some fibres of the brachialis anticus muscle, and it is possible that this may also have been the case upon the left side. Ruge* believes that in early fœtal life the artery of the limb occupies a position close to the inner border of the humerus, and that in the course of development its position is changed to the front. Any obstruction to this change, such as the presence of a supracondyloid process, he regards as preventing the artery from taking up its usual position, and probably also so retarding the circulation as to necessitate the development of collateral stems for the supply of the rapidly growing extremity. If this view be correct it is also possible that an obstruction might be caused by the presence of fibres of the brachialis anticus muscle in front of, and constricting, the artery. But it is obvious that, in addition to such a general theory, an explanation is required of the method in which, in different cases, certain channels below the seat of obstruction persist in connection with the main stem, while in others their place is taken by collateral branches.

(II.) In the right arm of a male subject, dissected in the summer of 1887, the following interesting abnormal details were noted:— From the superior profunda branch of the brachial a long slender trunk was prolonged down the arm to join the anterior ulnar recurrent artery, by which it was continued to the ulnar. The anastomosis took place at the lower end of the humerus, and at this spot the calibre of the aberrant vessel was slightly reduced in size. The vas aberrans lay upon the anterior surface of the internal inter-muscular septum, and gave off the inferior profunda in its downward course, while at the place of anastomosis branches were furnished corresponding in distribution to the anastomotic artery. With the exception of the absence of the anastomotic and inferior profunda branches, the distribution of the brachial artery was normal; it occupied its usual position, and was crossed from without, inwards, by the median nerve. There was no supra-condyloid process, nor did the origin of the pronator radii teres muscle extend higher up than usual.

* G. Ruge, "Beiträge zur Gefässlehre des Menschen;" Morphol. Jahrbuch; IX. (1884), pp. 327-388.

In the paper before mentioned Ruge * has pointed out that when two vessels are present in the upper arm one of them is always a "collateral stem," the result of an enlargement of anastomosing branches which in normal circumstances remain comparatively undeveloped. The collateral stem to which he calls attention is one which is formed of vessels distributed to the biceps muscle, anastomosing at the elbow with muscular and recurrent branches of the radial and ulnar arteries, and when enlarged occupying a position superficial to the median nerve. The case described above points to the presence of another line of anastomosing branches lying along the anterior surface of the internal inter-muscular septum by way of the superior and inferior profunda arteries, the anastomotic, and the anterior ulnar recurrent, capable of being so enlarged as to produce abnormal relations. It is interesting to note the results of enlargement of portions or all of this chain. Were the branches stretching between superior profunda, inferior profunda, and anastomotic considerably dilated, while the first and last of these vessels still retained their connection with the parent trunk, there would result an apparent splitting or "island building" of the brachial artery. Again, as in the present case, the moderate enlargement of the whole chain would produce a "vas aberrans" connected below with the ulnar artery; while a greater enlargement with failure of the proper root of the ulnar would result in one form of high origin of the ulnar artery.

EXPLANATION OF FIGS. I. AND II., PLATE XV.

1. Right side. 2. Left side.

Ax., Axillary Artery; *R.*, Radial; *Ul.*, Ulnar; *A. I.*, Anterior Interosseus; *P. I.*, Posterior Interosseous; *s.s.*, subscapular; *p. c.*, posterior circumflex; *s. p.*, superior profunda; *i. p.*, inferior profunda; *a.*, anastomotic; *a. u. r.*, anterior ulnar recurrent; *p. u. r.*, posterior ulnar recurrent; *r. r.* radial recurrent.

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* *Loc. cit.*

XV.

THE RELATIONS OF THE APONEUROSIS OF THE TRANSVERSALIS AND INTERNAL OBLIQUE MUSCLES TO THE DEEP EPIGASTRIC ARTERY AND TO THE INGUINAL CANAL.

By John Yule Mackay, M.D.

PLATE XV, Fig. 3.

The anterior aponeurosis of the transversalis muscle has been usually described as forming along with a portion of the aponeurosis of the internal oblique the upper part of the posterior wall of the sheath of the rectus abdominis muscle, and the semilunar fold of Douglas has been regarded as marking the lower limit of the disposition of these tendons behind the muscle.* The records of a large number of dissections made in the anatomical rooms during the last three years, during which period attention has been specially directed to this point, make it evident that this description does not conform to the anatomical facts.

Immediately external to the outer margin of the rectus the aponeurosis of the transversalis becomes intimately united with a portion of that of the internal oblique, and the united tendons sweep downwards and inwards towards the linea alba behind the rectus muscle as a single structure. Below the semilunar fold this sheath, while distinct and easily separated from the transversalis fascia behind it, is comparatively thin. It presents, however, a very constant arrangement of its fibres. Braune,† who has described the lower portion of the posterior wall of the rectus sheath, talks of it as if it were formed of the aponeurosis of

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* Quain's Anatomy. 9th edit. London, 1882, page 327.

† Braune: Das Venensystem des Menschlichen Körpers. Leipzig, 1884.

the transversalis muscle alone; but the fact that both muscles contribute to it is proved by the occasional presence of muscular fibres belonging to the internal oblique in the wall of the sheath below the level of the semilunar fold. From the fold of Douglas to a level a little lower than the middle point between pubis and umbilicus the fibres are disposed in a uniform manner, but below this line they are divided into two distinct bands.

One band passes downwards and inwards from the outer margin of the sheath towards the pubis to unite with the linea alba near the middle line. This band when specially strong gives the appearance, when the rectus muscle has been reflected, of a second semilunar fold considerably lower in position than the fold of Douglas. Between this band and the conjoined tendon, a very thin portion of the aponeurosis is stretched. The other band, beginning at the same spot, is directed downwards and outwards along the outer margin of the conjoined tendon, with which it is continuous, and, passing close to the inner and lower border of the deep abdominal ring, reaches the crural arch, into which it is inserted, extending outwards as far as the middle point of Poupart's ligament. Braune,* who mentions the presence of these bands, names them respectively Henle's band and Hesselbach's band.

The deep epigastric artery, immediately upon its origin from the external iliac, pierces the fascia transversalis, and is continued upwards in the abdominal wall, lying behind the band of Hesselbach, and in front of the fascia. The posterior sheath of the rectus is pierced by the artery in the angle between the two bands. Henle† believed the semilunar fold of Douglas to be an arrangement in special relation to the epigastric artery; but in the fœtus of six months, in which the semilunar fold is situated at the level of the umbilicus, the artery pierces the sheath much lower down, in the angle between the two bands described above, which are already, at that date, perfectly distinct. Professor Solger‡ regards the thickening of the sheath above the level of the fold of Douglas as especially connected with the movements of respiration.

The band of Hesselbach as it passes downwards touches the internal and lower margin of the deep abdominal ring, and being

* *Loc. cit.* † Henle; "Muskellehre," p. 68.

‡ B. Solger: "Ueber die Bedeutung der Linea Semicircularis Douglasii, Morphol. Jahrbuch, 1886; page 102.

continuous with the outer margin of the conjoined tendon, the floor of the inguinal canal is thus supported along the whole length by an aponeurotic band, and it is obvious that no hernial protrusion could enter the canal, except by way of the deep ring, without interfering with this structure.

EXPLANATION OF PLATE No. XV, Fig. 3.

a. Anterior wall of sheath of rectus abdominis muscle.
b. Posterior wall of do. do. do.
c. Semilunar fold of Douglas.
d. Band of Henle.
e. Band of Hesselbach.
g. Cord.
h. Crural Arch.
k. Rectus muscle drawn aside.
l. Pyriformis muscle.

XVI.

ON THE GROOVES SEPARATING THE PATELLAR FROM THE MENISCO-TIBIAL SURFACES OF THE FEMUR, AND ON LOCKING OF THE KNEE-JOINT IN FULL EXTENSION.

By R. Bruce Young, M.A., M.B., C.M.

PLATE XVI.

Most anatomists who describe the two grooves marking off the patellar from the menisco-tibial portions of the articular surface at the lower end of the femur,* look upon them as the result of pressure of the femur on the semilunar cartilages during full extension of the knee-joint. Langer, indeed, states† without further explanation that they are not solely the impressions of the semilunar cartilages, but the generally accepted theory is that they are, and this is supported by Terrillon in a paper specially devoted to the question. ‡ Heiberg, § however, rejects this explanation, and maintains that they are nothing more than the representatives in the human subject of the complete separation existing in some of the lower animals between the patellar and the two menisco-tibial surfaces of the femur.||

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* Henle—Luschka—Beaunis et Bouchard—Hueter—Morris—Meyer and Terrillon quoted by Heiberg in Arch. für Anat., His u. Braune, 1883. p. 171-2.

† Das Knie-Gelenk des Mensch., p. 6.

§ Jour. de L'Anat. et de la Physiolog. 1879. p. 35 *et seq.*

‡ Heiberg, *l. c.*, calls the grooves "vertieften Linien". This expression is, I think, insufficient, for the grooves are more than mere "vertieften Linien," and as there are both "Vertiefungen" and "Linien" marking off the parts of the femoral surface it is apt to mislead.

|| Panas also speaks of the grooves as being simply the lines of separation between the tibial and patellar surfaces of the femur (Terrillon, *l.c.*, p. 36.)

A careful examination of the semilunar cartilages and of the surfaces of the femur and the tibia, while leading me to question Heiberg's conclusions, at the same time brings out certain details which seem to have escaped the notice of those who hold the other and ordinarily received view.

The articular surface of the external tibial condyle, as Hueter points out,* instead of being, as usually described, concave, like that of the inner condyle, always retains in the adult somewhat of the fœtal form of a half-cone,† with its apex at the external tubercle of the spine. In the adult the pressure of the semilunar cartilage (and I should think also of the femur directly) produces a slight hollowing of the side of the cone; but in a vertical antero-posterior section there is still a convexity contrasting markedly with the concavity of the internal condyle. The part of the anterior and inner border of the external tibial condyle, which runs up to the external tubercle of the spine, forms an elevated ridge slightly curved—the concavity of the curve facing forwards and inwards.

As the external semilunar cartilage passes to its anterior attachment it bends over the anterior and inner border of the tibial condyle. In so doing it is gradually turned on itself until at its insertion in front of the external tubercle of the spine the two surfaces of the cartilage, which in the greater part of their extent were horizontal, are placed vertically, the thin central edge being turned upwards (Fig. 2). There is thus a part of the external semilunar cartilage which extends beyond the margin of the tibial articular surface. This part differs from the rest in having its fibres mostly parallel, and being consequently ligamentous in appearance.‡ Owing to this disposition of the anterior horn of the semilunar cartilage a small part of the anterior and inner border of the tibial articular surface towards the external tubercle of the spine is left uncovered, even when the knee-joint is in the flexed position (Fig. 2, *a*), while in extension of the joint, the anterior part of the semilunar cartilage being pushed forwards by the femoral condyle, the concave part of that border is fully exposed.

On the femur the groove which runs from the margin of the outer condyle to the intercondylar notch consists of two parts. Of these the outer, and by far the most distinct, is somewhat triangular,§ with its base at the outer margin of the condyle.

* Virchow's Archiv, vol. 26, p. 491. † Virchow's Archiv, vol. 26, p. 486.

‡ Humphry, Hum. Skel., p. 545.

§ Henle Anat. des Mensch., vol. 1, pt. 2, p. 132.

Always most deeply marked towards its base, this triangular part of the groove becomes shallower as it approaches its apex. The inner part of the groove, never so well marked as the outer, is most distinct towards the margin of the intercondylar notch.* There is generally a flattish shallow depression on the femoral surface extending some way back from the inner part of the external groove. The ridge running across the femoral surface in front of this groove, and forming its anterior limit, has a curved course, the convexity of the curve facing backwards and outwards (Fig. 1).

What happens when the knee-joint is brought to the position of full extension is that the external groove, owing to the rotation inwards of the femur, moves towards the anterior and inner border of the tibial condyle.† Its outer portion closes on the semilunar cartilage, the relation of the anterior part of the cartilage to the tibial condyle being such that a triangular surface is here pressed on by the femur. The inner part of the external groove, on the other hand, is pressed directly against the part of the tibial articular border which is left uncovered by the anterior horn of the semilunar cartilage. Its most distinctly marked part, *i.e.*, the part nearest the margin of the intercondylar notch, comes in contact with the anterior border of the external tubercle of the tibial spine, while the flat depression which extends back from the inner part of the groove rests on the sloping articular surface which runs up to the external tubercle.

This exact correspondence between the external groove on the femur, in its different parts, and the structures with which it comes in contact in full extension of the knee-joint, coupled with the fact that the grooves are not present on the femur at the time of birth but only develop as age advances,‡ seems to leave little room for doubt that the groove is the result of pressure, partly on the semilunar cartilage, partly on the anterior and inner margin

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* Hueter (*l.c.*, p. 497) describes the outer groove on the femur as consisting solely of what I have called its outer part. Though, however, the groove is less strongly marked in the inner part of its extent, I have as a rule found it, as described by most observers, extending to the margin of the intercondylar notch. Even where the groove is very faint in the middle of its course, the small inmost part of it is usually distinct.

† Cf. Hueter, *l.c.*, p. 490.

‡ Hueter, *l.c.*, p. 496, and Terrillon, *l.c.*, pp. 38-9.

of the tibial articular surface,* and that the pressure is greatest where the groove is deepest, *i.e.*, at its outer part.

Hueter† points out that the inner portion of the anterior border of the external tibial articular surface is depressed to a level lower than that of any other part of this surface (Fig. 2, *d*), the corresponding part of the inner tibial condyle having a relatively elevated position. This depression marks that part of the tibial surface on which the semilunar cartilage rests when pressed on by the groove on the femur, and its being much more distinct in the adult than in the newly-born infant is an additional proof of the action of pressure.

The part of the anterior and inner border of the external tibial condyle which in the adult is left uncovered is in the fœtus covered by the anterior horn of the semilunar cartilage. In the fœtus, too, it is fuller and does not present the slight concavity which characterises it in the adult. The exposure of this part of the tibial border, and its alteration in form, are due to the pressure which comes into play during life.

Just beyond the anterior and inner border of the external articular surface of the tibia, there is a groove on the non-articular portion (Fig. 2 *c*). More sharply defined in some cases than in others, it is always recognisable as at least a hollowing of the surface. Towards the close of extension of the knee-joint, the anterior part of the external semilunar cartilage slides over the convex anterior and inner part of the tibial condyle, till the groove on

* At page 179 of this volume several cases are mentioned in which the external interarticular cartilage formed a disc separating the articular surfaces of the external condyles of the femur and the tibia so completely that they never came directly in contact with one another in any position of the joint. In the two of those cases in which the markings on the surface of the femur were noted, confirmation was afforded of the view here put forward as to the cause of the inner part of the external groove. In both, though the outer part of the groove was marked, its inner part and the depression usually existing on the part of the femoral surface which rests on the surface sloping up to the external tubercle of the tibial spine were absent, the complete interarticular cartilage having prevented the femur from coming in contact with the tibia at those points. The ridge which marked the anterior edge of the external part of the groove in both cases was continued as a linear marking to the edge of the intercondylar notch, but in passing towards that notch it ran much more obliquely backwards than usual, the patellar surface of the femur being here prolonged backwards at the expense of the menisco-tibial.

† Hueter, *l.c.*, p. 490.

the femur, coming down on the cartilage from above, drives its peripheral margin into the groove on the tibia, and the running wedge is converted into a fixed one. Not existing in the child at birth, this groove on the tibia is developed as age advances, under the influence of that pressure which causes the grooves on the femur.

The groove on the inner condyle of the femur differs considerably from that on the outer. It does not extend, as the usual descriptions* would lead one to believe, right across to the intercondylar notch, but only exists on the inner part of the condylar surface. It is generally much less deeply marked than the outer groove,† and not so definite in form (Fig. 1, *c*).

When the internal semilunar cartilage reaches the anterior part of the articular surface of the tibia, it loses its wedge shape. Becoming ligamentous and flattened out, it passes outwards and slightly downwards to be attached beyond the articular surface on the front and inner part of the gap between the condyles. It is thus fixed at such a point as to be best able to resist the drag made on it by the internal condyle of the femur gliding backwards at the close of extension. At its anterior part the articular surface of the internal tibial condyle is bevelled off,‡ and on this small bevelled part the flattened ligamentous portion of the semilunar cartilage lies. Consequently at the close of extension the groove on the inner condyle of the femur rests, not on the whole anterior horn of the semilunar cartilage, but only on the part of it which is bending over the ridge, which separates the more horizontal from the bevelled anterior portion of the tibial surface. From the relation of the groove to the semilunar cartilage, and from the fact that, like the external, this groove does not exist in the child at birth, it seems plain that it is caused by pressure on the semilunar cartilage.

This internal groove, as we have seen, does not extend to the margin of the intercondylar notch. The ridge which runs in front of it is at its outer end prolonged backwards for some distance as a faintly-marked line, cutting off a portion of the articular surface lying along the anterior part of the inner margin of the intercondylar notch. This portion of the articular surface is,

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* Luschka, Anat. des Mensch., vol. iii., p. 368. Langer, *l.c.*, p. 6. Heiberg, *l.c.*, p. 173. Terrillon, *l.c.*, p. 37. Hueter, *l.c.*, p. 497.

† Cf. Luschka, *l.c.*, Beaunis et Bouchard, *l.c.* Hueter, *l.c.*, p. 497.

‡ Cf. Hueter, *l.c.*, p. 488.

as Goodsir recognised,* a prolongation of the patellar surface, with the rest of which it is directly continuous (Fig. 1, *d*). The line of separation between this surface and the anterior part of the menisco-tibial surface of the internal condyle is generally faint, and is often to be distinguished rather by the change of transverse curvature of the articular surface than by a well-marked ridge.

The existence of the patellar facet on the oblique part of the internal femoral condyle explains why the internal groove does not extend right across to the intercondylar notch. The femoral surface is so cut away to form the facet that at the close of extension the surface of the facet does not press on the anterior and outer margin of the tibial condyle, and so the internal groove is not continued beyond the part where the femur rests on the semilunar cartilage.

During extension the greater part of the movement at the knee-joint may be looked upon as taking place around a transverse axis, passing through the lower end of the femur.† When this movement around the transverse axis has reached its limit the anterior crucial ligament is tightened, so that the external condyle of the femur is prevented from passing any farther backwards. Up to this point the movement of the internal condyle has been similar to that of the external, but now, as extension of the joint proceeds, the pull of the tightened anterior crucial ligament on the outer condyle forces the femur to rotate inwards on the oblique anterior part of the internal condyle, the movement taking place around the oblique axis (Meyer) of the knee-joint. This movement of rotation is facilitated by the facet for the patella on the anterior part of the internal condyle being cut away to such an extent that this facet does not come into contact with the tibial articular surface, but sweeps freely round the internal tubercle of the tibial spine. Goodsir was wrong, I think, in holding that this facet at the close of extension "moves upon and is in contact with the internal anterior cartilaginous surface of the intercondyloid spine of the tibia; and with the tibial attachment of the anterior crucial ligament."‡ When extension has reached its limit the anterior crucial ligament and, it may be, the

* Anat. Memoirs, vol. II., p. 225. See also Meyer in Arch. für Anat. His u. Braune, 1880, p. 286.

† Meyer, Mech. des Knie-gelenks, pp. 501-2; and Goodsir, *l.c.*, p. 221.

‡ *L.c.*, p. 235.

internal tubercle of the tibial spine do come into contact with the femur, but it is with the anterior margin of the intercondylar notch, * and not with the patellar facet on the anterior part of the inner condyle. The anterior margin of the intercondylar notch of the femur sometimes shows a distinct indentation at the part where it comes in contact with the anterior crucial ligament in full extension. The pressure of the femur on this ligament must therefore be considerable and must help to check the movement of extension. If in full extension the internal tubercle of the tibial spine does come into contact with the femur at all (which I doubt), the locking of bone against bone at this point must be slight.

The movement of rotation at the close of extension of the knee-joint is also assisted by the somewhat conical form of the external articular surface of the tibia to which reference has already been made. During extension, when the movement on the transverse axis has reached its limit, the external femoral condyle presses on the anterior part of the semilunar cartilage which, resting on the conical slope of the tibia, slides forwards and inwards carrying the condyle of the femur with it.

Summing up as to the grooves on the femur, while it is true that they are developed by pressure, we have seen that the usual view which regards them simply as imprints of the anterior parts of the semilunar cartilages requires modification in the case of the outer groove which comes into contact with the free margin of the tibial condyle as well as with the semilunar cartilage. These grooves act, more especially the outer one, in checking the powerful movement of extension and in maintaining the stability of the knee-joint in the erect posture. In fact, when the femur is screwed home it and the tibia are by means of the grooves locked like one bone † after the fashion in which Goodsir thought that this was affected by the femur pressing against the inner tubercle of the tibial spine. The grooves are what Goodsir ‡ called terminal facets, *i.e.*, they are facets situated at the extremity of

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* Cf. Meyer, Arch. für Anat., His u. Braune, 1880, p. 286, fig. 2.

† Owing to the interposition of the semi-lunar cartilages the locking of bone against bone is for the most part indirect, actual contact of the bones only taking place at the inner part of the outer groove.

‡ *L.c.*, p. 236.

the line of movement on the femoral surface, and on them the femur comes to rest.

The closure of the external groove on the semilunar cartilage and on the margin of the tibial condyle, of the internal groove on the semilunar cartilage, and the contact of the intercondylar notch of the femur with the anterior crucial ligament must be taken along with the tension of the ligaments (lateral, posterior, anterior crucial and part of posterior crucial), in estimating the checks which act in limiting the movement of extension and in securing the stability of the knee-joint in the erect posture.

As I have mentioned before, Heiberg holds an opinion as to the origin of the grooves on the femur very different from that given above. In his paper on the subject he points out * that the outer of the two grooves very often has a curved course with the convexity of the curve facing backwards and outwards; and he argues that since the convexity of the curve of the anterior horn of the semilunar cartilage looks in the opposite direction, the groove on the femur cannot represent the impress of that cartilage. The margin of this part of the semilunar cartilage does indeed form a curve with the convexity facing forwards, and the external of groove on the femur, so far at least as the ridge running in front it and marking its anterior limit is concerned, has the convexity of its curve facing in an opposite direction (Fig. 1). At first sight, therefore, his argument seems to hold good; but we have seen that the anterior horn of the semilunar cartilage does not simply rest on a flat surface so as to be pressed on in its whole extent by the femur at the close of extension. It is so disposed on the tibial surface that the external groove on the femur comes in contact only with a portion of it, the inner part of the groove pressing directly on the margin of the tibial condyle. It is therefore with curve of these structures and not with that of the anterior horn of the semilunar cartilage that we should expect the curve of the groove on the femur to correspond, and this is what we actually do find.

Heiberg also states that the grooves on the femur, instead of showing an increase in depth, as age advances, are most distinct on those femurs which still have the epiphyses ununited, and that they tend to become obliterated on older specimens. My observations on this point, as I have noted above, agree with those of Hueter and Terrillon. In the Anatomical Museum,

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* *L.c.*, p. 173.

here, I find the most distinctly marked grooves on the older specimens, and not on those which have the epiphyses still separate. There are, it is true, quite distinct grooves on several femurs with the lower epiphysis still separate, but these specimens have the epiphyses of the trochanters and of the head united to the shaft, and must therefore have belonged to subjects of about the 18th or 19th year,* so that they have had time enough to become well marked under pressure. In younger specimens, the grooves are fainter.

As dry bones, however, are not to be trusted as affording reliable evidence on a question concerning markings on an articular surface, I also examined specimens on which the articular cartilage had been preserved, and find that in fœtuses, before and up to the time of birth, there are no grooves on the lower end of the femur.† In a child of about four years, the grooves are very faintly indicated. In a subject of 17 years, the grooves are well marked, while in several older specimens I find them most distinct, the outer always the better marked.

Again, by tracing on the lower articular surface of a femur the outlines of the semilunar cartilages, Heiberg‡ shows that in the position of full extension the anterior portion of each, instead of coinciding with the groove on the femur, crosses it, so that on each side there is a portion of the cartilage lying anterior to the groove. Therefore, he argues, the grooves on the femur cannot represent the impress of the semilunar cartilages.

It is quite true that, owing to the disposition of the anterior horn, both of the external and of the internal semilunar cartilage, there is a part of each on which the femur does not press at the close of extension; but the fact that a tracing on the femoral surface shows that a part of the anterior end of each semilunar cartilage passes in front of the grooves, in no way invalidates the statement that the part of the semilunar cartilage on which the femur is pressed, at the close of extension, leaves its impress on that surface.

He further says, that it is somewhat difficult to understand how the semilunar cartilages should by their pressure produce grooves on the femur at the precise points at which those grooves

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* Quain, 9th edition, vol. i., p. 124.

† Cf. Hueter, *l.c.*, p. 496, and Terrillon, *l.c.*, pp. 38-9.

‡ *L.c.*, plate vi., fig. 2.

occur, seeing that there are no ridges there, and that a checking of the movement never takes place there, that checking being, according to his view, brought about by the posterior and the lateral ligaments.

When the form and relations of the parts of the semilunar cartilages, and of the part of the margin of the external tibial articular surface with which the anterior parts of the menisco-tibial surfaces of the femur come in contact at the close of extension are taken into consideration, I fail to see the difficulty in understanding how the femoral surface should, even without the presence of ridges, become marked by grooves developed under a pressure which increases as age advances, and the influence of which they help to counteract. The ridges forming the anterior borders of the grooves develop as the grooves deepen. As to the checking of the movement of extension, no doubt, in young subjects this is mainly effected by the ligaments (lateral, posterior, anterior crucial, and posterior part of the posterior crucial); but as the weight borne by the femur and the consequent demand for greater stability at the knee-joint increase, the grooves on the femur are developed; and by closing on the anterior parts of the semilunar cartilages, and in the case of the outer groove, on part of the margin of the tibial condyle as well, aid the ligaments in resisting the tendency to over-extension.

In conclusion, Heiberg points out that on examination of the skeleton in certain of the lower animals (orang, elephant, lion, bear, sloth, kangaroo, porcupine, hyæna), he finds the grooves on the femur present, and argues that seeing these animals in standing have the knee-joint in a more or less flexed position, so that the grooves do not come into contact with the semilunar cartilages, the grooves cannot be due to the pressure of the cartilages.

Having thus satisfied himself that neither in the human subject nor in the lower animals are these grooves the result of pressure, he maintains that they are the representatives of the non-articular gaps found in the ox, camel, and llama, separating the articular surface of the condyles of the femur from that of the trochlea. As to the markings on the articular surface of the femur in the lower animals, I examined casts of this surface in the tiger and the racoon, which casts taken from the fresh joint surface represent its markings more truly than the dry bones, and I find that the lines of separation between the menisco-tibial and the trochlear surfaces are marked not by grooves but by ridges. I also examined the femoral surface on the dry bone in the orang, lion, bear, kangaroo, and hyæna,* as well as in the gorilla, puma, cat, and coati-mondi. In all these animals, except the orang, gorilla, and bear, the lines of separation of the different parts of the femoral surface, in so far as they are marked at all, are marked by ridges and not by grooves. Traces of one or both grooves are to be found in the orang, gorilla, and bear, but the fact that these animals have greater freedom of extension at the knee-joint than other animals, and at times assume a semi-erect posture, seems sufficient to account for the development by pressure of indications at least of the grooves which are found in the human subject.

So far, then, as my observations go, it seems that the lower end of the femur in those of the lower animals in which it is covered by a continuous sheet of cartilage generally presents two ridges marking off the different parts of the articular surface. In the human subject, however, in accordance with the need for greater stability in the fully extended knee-joint, and as a consequence of the great pressure which comes to bear on the joint, there are developed on the femoral articular surface two grooves which play an important part in checking the movement of extension, and in rendering the joint fixed in its extended position. These grooves only exist in their fully developed form in the human subject, but it is interesting, as bearing out the view that they are the result of pressure, to note the occurrence of indications of them in the orang, gorilla, and bear. The grooves on the femur in the human subject really belong to the menisco-tibial portion of the articular surface. The true lines of separation between the trochlear and the menisco-tibial surfaces in the human subject, and therefore the representatives of the ridges in some of the lower animals and of the non-articular gaps in others, marking off the different parts of the femoral articular surface, are the ridge in front of the external groove and the ridge which, after running in front of the internal groove, turns backwards and divides the prolongation of the patellar surface of the femur from the anterior portion of the internal menisco-tibial surface. The grooves are not the representatives of the lines of separation of the joint-surface; and so far from being rudimentary organs, as Heiberg holds, they

* Unfortunately, I have not had an opportunity of consulting the skeletons of the other animals mentioned by Heiberg.

perform an important part in the mechanism of the knee-joint. They are in reality features marking the higher development in the human subject of a joint which in man alone reaches its greatest perfection in the two essential qualities of joint-structure, mobility and stability.

EXPLANATION OF PLATE No. XVI.

Fig. I.—The articular surface of the lower end of the femur :—

a. Outer part of external groove.

b. Inner part of the same.

c. Internal groove.

d. Patellar facet.

Fig. II.—Upper end of the tibia with semilunar cartilages in position:—

a. Small portion of anterior and inner border of external condyle left uncovered by semilunar cartilage. The extent of this exposed part is increased when the semilunar cartilage is pushed forwards in extension.

b. Anterior end of external semilunar cartilage, turning on itself as it passes to its insertion. In this position the semilunar cartilage covers the concave portion of the anterior and inner margin of the tibial condyle.

c. Groove on tibia just beyond margin of articular surface of external condyle. Into this groove the edge of the semilunar cartilage is pressed in full extension of joint.

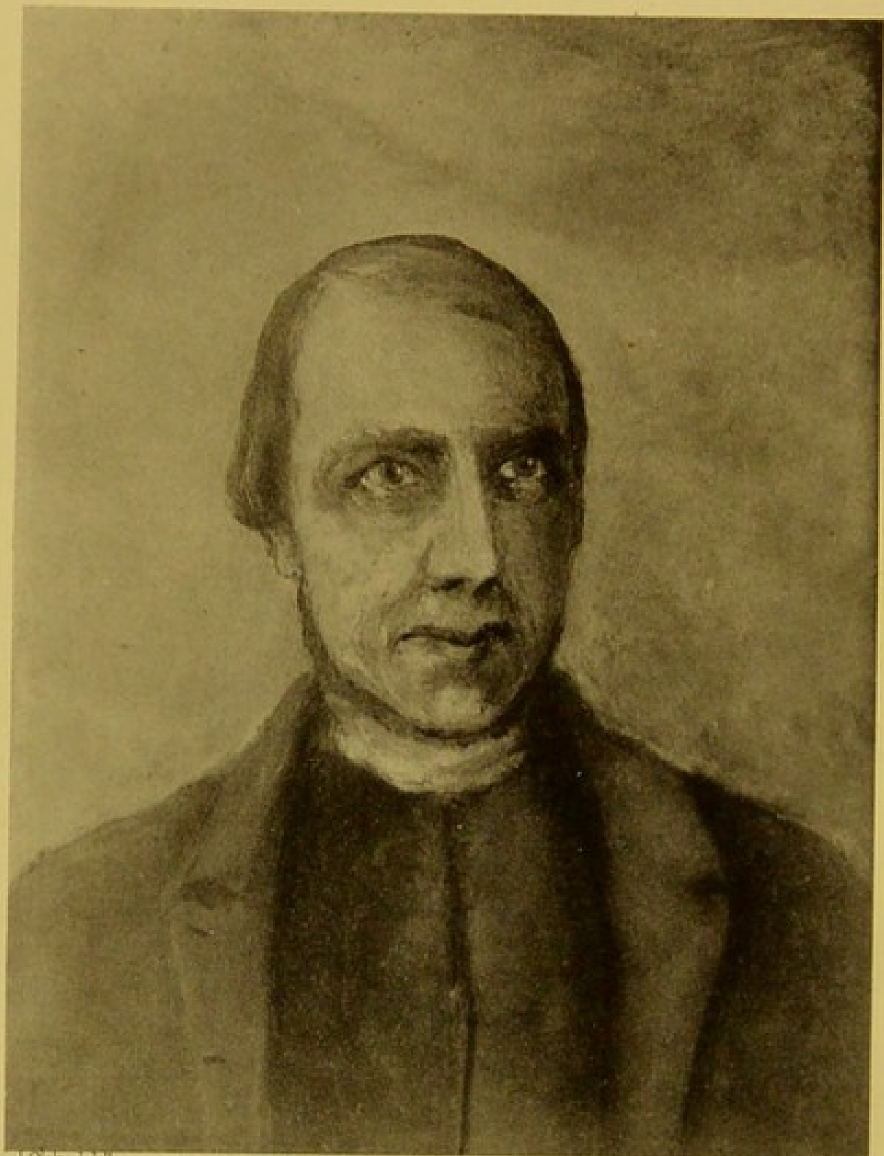
d. Depressed part of articular surface of external tibial condyle.

e. Anterior end of internal semilunar cartilage.

f and *g.* Anterior and posterior crucial ligaments.

h. The fibres passing from posterior part of external semilunar cartilage to join with posterior crucial.

The cut ends of the transverse ligament are seen towards front of semilunar cartilages.



John Goodwin.

MEMORANDA.

1.—Portrait of the late Professor Goodsir.

In offering to Anatomists a portrait of John Goodsir I need make no apology if, as I am fully supported in believing, I have fairly succeeded in reproducing the expression and form of his features. The portrait at the commencement of his collected works is not in the slightest degree like him, it represents a feeble old man with a little chin. But Goodsir's chin was massive and in keeping with his tall and powerful build, and there never was a trace of mental feebleness in his face. A photograph exists of him, which I have made use of, but it represents him with the painful effects of illness too visible in both face and figure. I have sought therefore to catch that happier expression with a lurking smile which was wont to animate his appearance when he was interested in conversation or in expounding his views in lecture; and as far as I could, I have endeavoured to recall him as he was before his illness, the robust surgeon and naturalist, as well as the philosopher who pointed out the agency of the nucleated corpuscle in both secretion and absorption.

Born March 20, 1814, he died March 6, 1867. It was only for a few years before his death that he took to wearing beard and moustache, which hid the highly characteristic mouth. In his dress he had certain peculiarities. He wore his waistcoat buttoned to the top, and lectured in a dress coat such as is now only worn in the evening, and for an introductory lecture used to appear with a white neckcloth on, without any fastening in front. It is in such dress that I have represented him. J. C.

2.—Acephalus.

The following specimen seems worthy of description, particularly as it does not seem to be obviously favourable to my theory of acephalus. No. 194 of my collection is an acephalous human fœtus, history unknown. Both legs show constrictions tending to intra-uterine amputation. The integument of the penis is large and thickened; also a fold of loose integument lies like a hood behind the upper part of the body. There are no traces of upper limbs. Dorsal vertebræ and ribs are developed; and above these a nodulated structure is seen, apparently an imperfectly developed cervical and cephalic skeleton, for above it there is a minute pouch surmounted by a projection of integument, and these both present a similarity to the indications of sense-organs found in perocephalous monsters. External to the ribs on each side is a bursa. Within the grasp of the ribs, reaching to near the top of the thorax are the kidneys. The intestine ends superiorly close to the umbilicus, and thence may be traced downwards. It reaches the cæcum after a course of an inch and a half. The great intestine is irregularly coiled, and ends below in a blind dilatation of the rectum in the upper part of the pelvis. The right testis is seen in the abdomen, while the left seems to have been absent. Of this specimen it may be remarked that, on the supposition that the small depression referred to is aural or stomato-aural, the specimen cannot have been united to another embryo by any part lower than the mouth. The idea also occurs that it may have been unassociated with any other embryo; but against that idea there is the important evidence that the specimen in its whole conformation belongs to the fifth type of acephalus recognised by W. Vrolik in the article "Teratology," in the *Cyclopædia of Anat. and Phys.*, and that such acephali are always associated with another fœtus; and although one might imagine that the absence of upper limbs and appearance of absence of the head were both due to such strangulating causes as had almost amputated the lower limbs, no such hypothesis will account for the acardiac condition, and absence of the upper half of the alimentary canal with its appendages. Altogether, therefore, I apprehend that the probability is that the specimen was separated at the head from another fœtus to which it had been appended. It reminds me of the very rare cases in which equally developed fœtuses have remained united by the forehead or vertex, and also of the remarkable skull, described by me (*Jour. Anat. and Phys.*, Jan., 1879), in which there was united with the proper skull of a full-grown fœtus another skull facing it, whose proper body had entirely disappeared. Thus we seem to have a series of three results of union at the fore part of the head, viz., twins united at the forehead, appendix growing from the front, and acephalus which has been broken off at that part.

J. C.

3.—Spina-bifida and Anencephalus in an early stage.

I owe to Dr. James A. Adams a specimen of anencephalus with spina-bifida extending the whole length of the column, in a human fœtus measuring two-thirds of an inch. I counted it exceedingly interesting because round about the open neural canal it exhibited ragged and torn walls separating the canal from the surrounding integument, and manifestly the burst superficial parietes of a dropsical sac which had extended through the canal in its whole length. It need scarcely be pointed out that a case of this sort at so early a date is a very important corroboration of the view of Lebedeff, to which I have elsewhere expressed adherence, that anencephalus and open spina-bifida are the result of an early dropsy which has burst, or, in other words, that rachischisis and cranioschisis are effects of hydrorachis and hydrocephalus. I have prepared the skeleton of the head and column, and they show similar conditions to those found in cases frequently met with at a later period. The face, however, appears to have been also affected, the nose consisting of cartilages mesially united, but with the external and lower edges free, while the maxillary lobes have come together as in cyclopia, without the middle frontal process taking part in the formation of the upper jaw. The arch of the lower jaw is short and thick, while the apertures of the ears have been approached one to the other inferiorly. The upper part of the vertebral column is split down the middle line of the bodies, all the way from the atlas to the sixth dorsal vertebra, in the same fashion as is known to occur sometimes in older specimens, the separated moieties of the divided bodies being considerably broader than they would have been had they been unseparated. J. C.

4.—Spina-bifida with Bony Projections into the Spinal Canal.

Since the appearance of Professor Humphry's important memoir on this subject (*Jour. Anat. and Phys.*, July, 1886), I have, probably like others, sought for the explanation of these bony projections. I think that the work in which I have been engaged has enabled me to find it. Professor Humphry evidently suspects that they have a morphological significance, and in this he is undoubtedly correct. Their shapeliness and in some cases their sequence and separate centres of ossification indicate that much.

But I think further that those who read what is brought forward in this volume in the memoir on "Birds with Supernumerary Legs" will scarcely find room to doubt that the bony projections in question owe their origin to partial fission of the early embryo. The precise nature of the fission may possibly vary in different instances. But as the anomaly in all the six cases recorded by Humphry has been in the lumbar region or lower end of the dorsal, the fission has most probably been abcaudal in them all. From what I have said in the memoir referred to, it will appear that the circumstance that the vestiges of duplicity are on the dorsum makes it probable that the duplicity has not taken the form of an appended twin, but has followed that other course there explained, in which the further limb of the suppressed division of the trunk is incorporated with the developed division, while the adjacent limbs of both divisions are dwindled. What I believe to have taken place in these cases of spina-bifida with bony projections is that the adjacent limbs have disappeared completely, while vestiges of the duplicity of the vertebral column are left at the seat of bifurcation. An outlook may be kept in future for some small vestige of appended limbs in these cases.

The posterior position of the supernumerary centres of ossification in these cases of spina-bifida is in harmony with the posterior position of origin of the supernumerary nerves in the case recorded by von Baer, referred to in the following memorandum, and in another case, observation VII. of von Baer's memoir.

J. C.

5.—Appended Fore-limbs.

Von Baer in his Memoir "Ueber Doppelleibige Missgeburten," observation VII. (*Trans. Imp. Acad. St. Petersburg*, VI.), describes an anomaly, so far as I know unique, which I find is susceptible of an exceedingly interesting explanation. The specimen was a cow with two supernumerary fore-limbs arising from a composite scapula and hanging from the left side of the neck. Its true nature did not dawn on me till I was engaged in framing a classification of anomalies. Then I perceived that, if in abcaudal fission it frequently occurs that one of the divisions of the trunk disappears, leaving its further limb to become approximated to the persistent division of the trunk, while the two adjacent limbs of the two divisions persist in a dwarfed and more or less composite condition, it is only reasonable to expect a similar phenomenon occasionally in connection with abcranial fission. No sooner does this suggestion occur than it is seen to suit exactly for explaining the case of the cow described by von Baer. It may be difficult to settle the question clearly; but von Baer's description is so explicit that, as a principle is involved, it may be better to consider what can be made of the evidence than to wait an uncertain and indefinitely long time for another anomaly of the same kind. The appended limbs were imperfect, supported by a common composite scapula, and the elongated bones presented such deviation from the normal as is common in supernumerary pelvic limbs. Each limb possessed only one principal and one supplementary toe. But the principal toe of one of the limbs presented a well formed pastern, coronet, and hoof-bone. The union of the united scapulæ is by the posterior borders, the dorsum looking outwards and the two spines backwards and forwards, so that the anterior part is a left scapula and the posterior a right scapula; and von Baer determines, evidently correctly, the anterior limb to be a left one and the posterior to be right. This is just what one would expect according to the new explanation. The double scapula and limbs were surrounded with fat, without muscles, and both limbs were supplied by a nerve which arising in a manner not altogether clearly made out, in connection with the roots of the regularly disposed fifth and sixth cervical nerves, escaped mesially from the dura mater to pass out between the ununited laminæ of the fifth cervical vertebra, then pierced a foramen left between the united borders of the double scapula and supplied both supernumerary limbs. If a similar anomaly could be obtained, the structure of the spinal cord, where the supernumerary nerves are given off, would be specially worthy of study. Between the supernumerary limbs there hung a projection with a blind pouch toward its extremity. This, according to von Baer, might represent the back part of the body of an appended embryo, with indications of a vent. According to my view it is the cephalic end of an undeveloped product of abcranial fission, and the pouch is buccal. Its morphological position would be behind the posterior supernumerary limb, that is to say, between it and the left developed limb, these being the two limbs to which it originally belonged; but it is easy to conceive how the right appended limb (the posteriorly placed limb) growing more rapidly than the aborted body and becoming elongated, might overhang it and come to lie behind it. Plainly, the case is one not of abcaudal but abcranial fission, and this being granted, the question to settle is whether the supernumerary limbs both belong to an appended left division of the embryo (in which case the left developed fore-leg belongs, like the head and the other limb to the right division of the embryo), or whether, the left division of the trunk, together with the adjacent left and right legs of the right and left trunks respectively, have been crushed out of shape, while the right division of the embryonic trunk and the left limb of the left division have completed a normal result between them. The arrangement of the double scapula and the analogy of what happens in the case of supernumerary pelvic limbs makes the latter explanation probable.

J. C.

6.—The Movements of the Metatarso-phalangeal Joints.

There are probably few subjects on which misconception is more prevalent among men who ought to know better than on the movements of the metatarso-phalangeal articulations. Everyone knows that when the two feet are laid together on the flat ground, their inner borders ought to be parallel in their whole length; or, to put it more exactly, when they touch at the heels and the balls of the great toes, these toes ought to lie in contact in their whole length. In old statuary, one even sees the great toe inclined inwards, but that is apparently intended to denote the pressure at the base of the toe exercised by the strap of the sandal. Shoes are, however, made so that when placed side by side there is an angular interval between the great toes; and ever since the publication, many years ago, of Professor Meyer's pamphlet, "Procrustes ante portas," there have been numbers of people who have thought this sufficient evidence that bootmakers distort the feet. Yet this is not really the case when the shoes are made to fit comfortably. A mocassin is made of such soft material as to adapt itself to the shape of the foot. Yet if worn for a while, it gets turned up at the toes, and the mark of the great toe shows an outward inclination, such as would be given to it by a shoemaker. The reason is not far to seek. If any one with the toes undistorted, so that the inner edges of the great toes continue forwards in a line with the inner edges of the feet, raises his toes from the ground by over-extension, his great toes will be seen separating and leaving an angular space between. The movement is a simple one, and can be appreciated at once by considering the extremities of the five metatarsal bones as one block. Then it will be seen that a line passing through them from the first to the fifth will lie in the axis of a cone, and that it is on the surface of this cone that the series of first phalanges revolves in the movement of over-extension. The path of movement can be read easily enough on the surfaces of the ends of the metatarsal bones, and it is the conical character of the movement which separates the toes of the two feet from one another. When the shoemaker turns upwards the point of the shoe he makes up for the outward inclination which he gives to the inner edge, and has merely followed the pattern made for him, not by mocassins only, but by the mould given to all thin flat slippers when they have been worn for a while. I own, therefore, that while I have often admired Professor Meyer's observations on joints, I have never been able to see the wisdom of his directions for reforming the shape of shoes.

J. C.

7.—The Metacarpo-phalangeal Articulations.

One of the most interesting results of the employment of helicoid curves in joints is to be found in the metacarpo-phalangeal articulations. The lateral ligaments are attached far back on the metacarpal bones, so as to be much nearer to their inferior ends than to their palmar aspects. In consequence of this, as correctly stated by Luschka, but probably not generally as much appreciated as it should be, the ligaments "are the more strongly stretched the more that palmar flexion proceeds forwards, and a corresponding arrest of the lateral movements goes hand in hand with this." (Luschka, Anat. des Menschen III., 145.) In point of fact, when the metacarpal bone is allowed to hang from the phalanx by the dissected lateral ligaments, there is a gap of $\frac{1}{8}$-inch or more between the bones in the extended position, while they are pressed firmly together when the joint is flexed; and if, when the hand is shut, a pencil be introduced between any two fingers, they immediately come together again when it is removed, because, as pointed out in the seventh and subsequent editions of Quain's "Anatomy," the first phalanges, as they become flexed, are confined each to one plane of movement, and their planes of movement converge the more rapidly the further that flexion is carried. I do not know if it has been noticed that it is in consequence of this form of the metacarpo-phalangeal joints that they undergo over-extension in deformity from rheumatism, notwithstanding that the flexor tendons are far stronger than the extensor tendons. The lateral ligaments, becoming contracted by inflammation, are tightened in the extended position in which they are usually slack, and thus flexion becomes impossible, and the heads of the metacarpals being in front of the ligaments drive them back by becoming swollen, so that the phalanges are thrown into an unnaturally over-extended position. The noise called cracking the fingers is produced by the phalanx, momentarily pulled away from its contact with the metacarpal, springing back into contact therewith; and it is the looseness of the lateral ligaments which allows the separation, while probably the circumstance which prevents the cracking sound being immediately repeated is the dragging into the joint of a small amount of fluid.

J. C.

8.—Later Fœtal Development of the Vagina and Uterus in the Human Subject.

Probably the usual impression is that those organs are exceptional which do not develop evenly, *pari passu* with the increasing size of the whole body. Perhaps it would be more correct to lay down the law that different organs and parts of organs grow at different rates at different times. This is notably the case with the kidneys, the liver, the ductless glands, and the different regions of the brain and skull. In the case of the uterus and vagina, the sudden increase of growth at puberty is matter of notoriety, but it does not appear that the unevenness of the rate of growth in fœtal life has sufficiently attracted attention. Many years ago I prepared and deposited in the Anatomical Museum of the Queen's College, Galway, where it ought still to be found, a specimen showing, among other things, the uterus and vagina of a fœtus, probably in the early part of the sixth month, with the vagina filled up with large papillary ridges in its whole extent both of height and circumference, contrasting with the interior of the uterus, which was perfectly smooth in the fundus, and marked only by fine longitudinal and transverse lines on the cervix. The large proportion borne by the vaginal ridges to the size of the organ, rendering its appearance very different from a miniature of the adult condition, struck me at the time, as well as their distribution over the whole surface. Symington (Topographical Anatomy of the Child, p. 75), states that "Kölliker says that he knows no organ that varies, in different subjects of the same age, so much in its size and development as the uterus, during the latter months of fœtal life, in the new born child, and the girl up to puberty." I have not seen Kölliker's paper, but it does not appear from the account in the "Jahresberichte" that either Kölliker in his paper in the Verhand. Phys. Med. Gesellschaft zu Wurzburg, 1881, or Geigel in the same society in 1883, have noticed the remarkable rapidity of growth of the vagina and uterus at a period between the fifth and seventh months of fœtal life, and this oversight may very easily have deceived Kölliker into making the statement alluded to, so far as fœtal life is concerned. To show that there is more than can be accounted for by variation in different individuals, it will be sufficient to contrast two dissections, one of a fœtus younger, and the other of a fœtus older than that which furnished the Galway specimen. In a fœtus which measured from vertex to coccyx 6 inches, and 9 inches with the legs stretched, the uterus and vagina together measured three-quarters of an inch in length, the uterus being quarter of an inch long. Both fundus and cervix uteri had the cavity exceedingly small and difficult to display, and the os externum had not begun to project down into the vagina. The walls of the vagina consisted of an anterior and posterior, meeting at each side in a sharp fold, the greater part of the surface being nearly smooth, but the lower part of the anterior wall exhibiting when viewed with the lens thick set papillosities. In another fœtus, measuring nine inches from vertex to coccyx, and fourteen inches with the legs stretched out, the uterus and vagina measured two inches and a half in length, the uterus was seven-eighths of an inch long, and projected three-eighths of an inch into the vagina, the projecting part consisted of corrugated membrane, and the posterior lip was the longer. The vagina was a circular cylinder nearly half-an-inch in diameter, and was filled up by four great projecting ridges, one in front, one behind, and one at each side. These longitudinal ridges were composed of series of more projecting parts of transverse ridges, each carried round the vagina and having nodulated or papillose edges, and the transverse ridging was not only carried to the top of the vagina, but continued distinctly over the projecting part of the cervix uteri. This is the general arrangement in a fœtus of seven months, and contrasts remarkably, not only with the earlier condition just described, but with the appearance before puberty, when for a second time the walls are proportionally thin and smooth, the roughness confined to the lower and anterior part, and the cervix uteri projecting into the vagina very slightly.

In the latter half of fœtal life, then, there is undoubtedly a period of exaggerated growth of the vagina and uterus, but especially of the vaginal ridges; and even when the character of the mucous membrane is kept out of view, it is a remarkable circumstance, in comparing two fœtuses, that while the increase in the length of the whole body from vertex to coccyx was only one half, namely from six to nine inches, the increase in length of the uterus and vagina was three times and a third, namely from three-fourths to two-and-a-half inches; that is to say, that on the supposition of growth having been similar in the two fœtuses, the uterus and vagina grew in length between six and seven times as rapidly as the rest of the body. This seems to agree perfectly with the table of dimensions published by Tourneux & Legay *(Jour de l'Anat. et de la Phys., 1884)*, but these authors seem to have failed to draw the right conclusion.

J. C.

9.—The First Rib in the Human Subject.

It is common enough to hear it said that the first rib lies flat on a table, a statement which is obviously incorrect; but even works on Descriptive Anatomy are too vague on the subject, and do not mention the real character of the curve. If the neck of the rib be held horizontally, and the rib allowed to slope a little downwards as it passes forwards, it will be seen that not only is the outer edge of the shaft a little lower than the inner edge, a circumstance usually adverted to, but there is a concavity of the upper surface of the shaft, extending over its whole length. I believe that character to be constant even in those instances in which, at first sight, it seems to be absent. Until quite recently, I had been in the habit of supposing that this was the effect of muscular action; but it is not so, for the concavity is most marked in young subjects. At birth it is striking, and in a fœtus of the fifth month still more strongly developed. In ordinary breathing, the first rib remains in the depressed position, the upper end of the sternum stationary, and it is subjected both in quiet and in full respiration to the accumulated drag of both external and internal intercostal muscles pulling its outer edge downwards, while on the other hand the opposed action of the scalenus medius and scalenus anticus is only occasional, but when brought into play is, no doubt, powerful, and that of the scalenus anticus has the advantage of good leverage. It may, therefore, be a question how far the scalene muscles are effectual in preventing the intercostals from increasing the downward curve of the shaft. But it is more important to note, that the attachment of the scalenus anticus has a very different relation to the ossified rib at different ages. During the fifth month of fœtal life, the part of the rib to which the scalenus anticus is attached undergoes ossification, and in the adult rib the projection marking the attachment of that muscle to the inner edge of the rib is about an inch-and-a-half away from the tubercle of the rib, and usually occupies the middle of a straight line between the tubercle and the outer edge of the extremity of the shaft. If then, the Hunterian law that bones do not grow by interstitial expansion holds good with regard to the first rib, we must suppose that the elongation behind the scalene projection, namely a growth of an inch or more, is effected in the same way as was demonstrated by Humphry's experiments in the case of the lower jaw, that is to say by absorption at one part and addition at another, the absorption taking place in this instance on the front of the neck of the rib, and the additional deposit on the back of that part. But in the majority of adults there is nearly as great a length of rib in front of the scalene eminence as behind it, the growth taking place by ossification from cartilage at the extremity. Applying these considerations as to the growth of the first rib to the history of its curve, it will be seen that the part in front of the scalene eminence has nothing to do with the well developed concavity of the upper surface seen in the fœtus, and that, further, this part while cartilaginous will rather tend to develop a downward concavity by being pulled upwards by the scalene muscles, and held down to the sternum in front. Indeed in the succeeding ribs this action seems to show itself by slightly increased downward slope of the extremity of the shaft which is the last part to be ossified. In young skeletons one sees that the scalene eminence has reached the permanent distance from the tubercle long before ossification at the extremity of the shaft has ceased. Principally, the nearer approach to flatness in the adult depends on the manner in which the added material is deposited on the part of the bone posterior to the scalene eminence; for it has already taken place by the time that the eminence has reached its permanent distance from the tubercle of the ribs.

J. C.

10. The Hairs of Ornithorhynchus.

Sir Everard Home (Phil. Trans., 1802, p. 89), speaking of the hair of Ornithorhynchus remarked—"the portion next the root has the common appearance of hair, but for quarter-of-an-inch towards the point it becomes flat, giving it some faint resemblance to very fine feathers." The phenomenon in question is much more interesting taken in connection with the spines of Echidna. The flatness is not the only peculiarity of the expanded part. The exceedingly slender stem, on the extremity of which the expansion is placed, is flat also. The expanded part is thickened as well as broadened, though not nearly to the same extent; and on the back of the animal it is scooped on one side like a lanceolate leaf, and the air-cells continued on from the slender portion in two or three rows are enlarged. But in the tail the expanded part stands straight out like a spine and is not so flattened; moreover, it is supported on a much shorter slender portion, likewise rounded, just as a spine of Echidna has a slenderer part at its base. The hair of the tail might, with a show of probability, be looked on as the first stage of a development toward spines, but it seems impossible so to regard the hairs of the rest of the body, which, in the greater part of their extent, are particularly delicate. On the other hand, it is easy to account for all the appearances on the supposition that the spines are vestigeal.

11. Supplementary Observations on Mammalian and Piscine Stomachs.

In writing on "The viscera of the Porpoise and White-nosed Dolphin" (*Jour. Anat. and Phys.*, April, 1884), I made a number of remarks on the morphology of the stomach in different animals. I referred to the ruminant panch as being simply a cardiac fossa with a letter-S curvature. I may further add what may possibly have occurred to others, but has not, so far as I know, been made subject of comment, that the muscular fibres which lie in the edges of the constriction forming the valve which separates the panch and reticulum from the third stomach, are exactly homologous with the oblique fibres in the human subject, those described as forming the "*Cravate de suisse.*" (See Küss, Manual of Physiology, translated by Amory, p. 235). This is the more interesting as the function of the fibres is somewhat similar, for according to Larger the *cravate de suisse* shuts off the cardiac part of the stomach, while it leaves a direct communication between the œsophagus and pyloric end, just as the first two stomachs are shut off in the ruminant when the food is swallowed a second time.

In the same memoir above referred to, I have drawn attention to the correct appreciation by Stannius that the receptive bag of the abdominal alimentary tube in Chimæra receives the bile duct, and is therefore not properly to be called a stomach, a remark which holds good also of Orthragoriscus, but it has since occurred to me as curious to note that no one has argued in the same way from the position of the pneumatic duct in certain osseous fishes. The swimming bladder is known to be an outgrowth from the alimentary canal, and its homology with the lungs is not doubted, even in the work of F. M. Balfour (Comparative Embryology, II., 630), although that writer admits the development to be imperfectly known. I quite agree that whatever difficulty there may be in accounting for certain details, it is in the last degree unlikely that lungs and swimming bladder do not correspond. But if that be so, the pneumatic duct which is the neck of the outgrowth from the alimentary canal must correspond with larynx and trachea, which are the neck of the hollow outgrowth developed into lungs. In that case, the pneumatic duct of the fish is always the same pneumatic duct, and the part into which it opens must be morphologically pharynx. But in the herring the pneumatic duct is continued from the hindmost end of the pointed abdominal receptive pouch, habitually termed stomach. This pouch, therefore, although within the abdomen, is pharyngeal. Between it and the suprabiliary valve or true pylorus, which is situated above the pyloric appendages, is a pyloric compartment, which is the true stomach. The mackerel has no swimming bladder, but its stomachic arrangements are similar to those of the herring, its pyloric compartment is well developed, and cut off by a distinct constriction from the receptive pouch which passes back to a conical point like that from which the pneumatic duct of the herring is continued. There can be no doubt that this cavity corresponds with that of the herring, and is therefore, strange to say, really pharyngeal. Van der Hoeven mentions two "very similar species from the Mediterranean," *Scomber colias* and *Scomber pneumatophorus*, in which the swimming bladder is present, but, as I have no opportunity of seeing them, I can say nothing as to the pneumatic duct in them. I should certainly, however, like to know if there is any development of swimming bladder in the embryonic condition of *Scomber scombrus.*

Taking into consideration that certain elasmobranchs, *e.g.*, Lamna and Scyllium, have a pyloric compartment cut off by a constriction from the main stomach, and similar in appearance to the pyloric compartment in the herring and mackerel, one might easily be tempted into supposing that in elasmobranchs, and an indefinite number of other fishes, the great receptive pouch was as much pharyngeal as in the herring and mackerel, but such a supposition is forbidden by the usual position of the orifice of the pneumatic duct in both ganoids and osseous fishes. The orifices of the pneumatic and bile ducts, the attachment of the umbilical vesicle, and the position of the cæcum are points which may be taken as fixed, while in different animals there is a great difference in the development of the five sections of the alimentary canal which these landmarks separate.

J. C.

12.—Renal Cord of Lamna Cornubica.

In two specimens of Lamna cornubica, I have noted and preserved a remarkable structure such as I have not met with in any other animal, and I am not aware that it has been described. The structure in question is an elongated mesial solid cylinder or cord between the kidneys in front, and imbedded in their conjoined substance further back. The specimens of Lamna were both between seven and eight feet long. The kidneys are about one-and-a-half feet long. They are united in the greater part of their extent, ending posteriorly in a thick blunt extremity a little behind the vent, while they are prolonged forwards in front in slender extremities distinct one from the other. In the extent in which they are united, they have a mass of erectile tissue between them ventrally, one of those vascular developments which are so remarkable in Lamna, there being a pair of them opposite the attached part of the liver, and a great *rete mirabile* in the muscular substance in each side of the body. Separated from the erectile tissue by renal substance, and lying in the dorsal edge of the fused kidneys, is the remarkable cord to which attention is called. This cord begins a little in front of the posterior extremity of the united kidneys, and acquires soon its greatest thickness, which is more than half-an-inch. It is of yellow colour, is surrounded by a thin sheath, and is of firm consistence, tough like leather under the knife, but friable when forcibly bent. It becomes thinner in front as the kidneys become slender, and between their separate extremities is somewhat flattened and bent from side to side before, in the one specimen, terminating in a point, and in the other being prolonged in a long and slender thread. Under the microscope it presents a reticulated appearance, as if divided into a number of large cells with slender walls, like the cells of the notochord of a sturgeon; and these are filled with structureless substance which resists the action of ether and chloroform, and is difficult to stain. It is difficult to imagine a function for this structure, and I can only conjecture that it has had its origin in common with the notochord.

J. C.

13.—The Incus, Stapes, and Styloid.

To Professor Fraser, of Dublin, belongs the credit (Phil. Trans., 1882,) of demonstrating that Reichert was mistaken in believing that the stapes and styloid process are originally connected by cartilage. Curiously enough, however, I find that the styloid process and the ossicles of the ear really are connected in another way. The styloid process is originally continuous with the posterior process of the incus. I have seen this in the human subject, in the pig, and in the sheep. I merely make a preliminary note of the fact at present, leaving to a future occasion the working out of the subject in detail. But I may mention that I was led to look for this connexion by having recognised that the stapes is the opercular of the fish, and that therefore the opercular process of the hyo-mandibular bone is the descending process of the incus, and it was probable that the portion of the hyo-mandilular connected with the hyoid arch was the posterior process of the mammalian incus. Forthwith I examined the sheep's skull and found that the styloid remains after birth as a separate element caught in a groove of the tympanic bone, and traceable up to the posterior and upper edge of the tympanic ring. Further examination showed me that this was the spot to which the incus was attached, and I then proceeded to examine the young embryo. But if my theoretical view be correct, the hyo-mandilular is common to two arches of different natures, the hyoid and the mandilular; and the descending process of the incus, or opercular process of the hyo-mandilular, supports a radiation. In that case the head of the stapes is the proximal end of that bone, and the impaction of its footplate in the fenestra ovalis must be secondary. So far as I have gone in my examination I am confirmed by observation in this belief.

J. C.

14.—Flocculus.

Though the development of the third cerebral vesicle has been in its general features very well known, it does not seem to have been generally recognised that a direct consequence of the mode of first appearance of the cerebellum and of the flocculus is that these parts are morphologically totally distinct. It is the easiest thing in the world to demonstrate in the sheep or in the fowl that the first appearance of the cerebellum is as a mesial lamina passing backwards from the anterior limit of the third cerebral vesicle, and that the mammalian and avian cerebellum is a mesial dorsal pouch quite comparable with the piscine cerebellum. In fact one already sees in the elasmobranchs the transverse lamination of the pouch and the intrusion behind it of the choroid plexus of the fourth ventricle. The nidus avis is the original pouch-cavity, and the free edge of the posterior velum is the edge which was originally directed backwards, separated on each side by a transverse fissure from what afterwards is folded outwards to become the outer edge of the ligula. Thus there is altogether an originally ⊤-shaped breach of continuity in the cerebral cylinder, by which the choroid plexus of the fourth ventricle intrudes, repeating very much the state of matters further forwards, where the choroid plexuses of the lateral ventricles enter by fissures directed outwards, and the plexus of the third ventricle projects through a longitudinal fissure meeting them in the middle. But if the fissure between posterior velum and ligula be followed outwards it leads to the flocculus, which is developed, as is easily seen and well known, from the walls bounding the extremity of this fissure. This fissure, which may be termed the *transverse fissure of the fourth ventricle*, and extends from the hollow peduncle of one flocculus to that of the other, lies in the concavity of the bend forward of the upper part of the medulla oblongata, while the cerebellum is developed from the overhanging convexity backwards, its anterior and upper part appearing first. Thus the cerebellum is mesial, the flocculus lateral, and the cerebellum originates from a part of the third vesicle further forward than the flocculus. It is worth while pointing out that the optic vesicles are lateral outgrowths, and that there is no reason why the olfactory bulbs should not be considered as lateral outgrowths, also that the nuclei of the auditory nerve lie close to the flocculus, and that the flocculus "is large in the cat, the aye-aye, the timid rodents, and all the small mammals with acute hearing" (Owen. Comp. Anat. and Phys. of Vertebrates, III., 158). I have no doubt that olfactory bulb, primary optic vesicle and flocculus are serially homologous structures.

J. C.

15.—The Canal of Petit.

I do not enter at present on the nature of the boundaries of this canal, nor on the question of tissue existing within it. It is sufficient for my purpose that there is an injectable space surrounding the edge of the capsule of the lens. The plications of the zonule of Zinn invade its anterior wall, the suspensory ligament of the lens. But these plications cease on arriving at the edge of the capsule or a little away from it, and in specimens treated with bichromate of potash and very weak spirit, each ridge corresponding with the interval between two ciliary processes, and therefore distinguishable as an interciliary ridge, can be seen to terminate in a free elevation or process, so that there is a circle of such processes standing out round the lens visible in a good preparation. In the ox and goat each interciliary ridge is pinnate. The ridges and processes are easily injected with vermilion by sending the nozzle of the syringe into the canal of Petit. Within the circle formed by the roots of these processes the suspensory ligament extends smoothly on to the anterior wall of the capsule; but in injected specimens the vermilion may be seen extending forwards on the anterior wall of the capsule in a series of short lines or projections underneath the suspensory ligament. Only once have I been able to see these linear projections carried forward in fine threads over a considerable part of the lens; and in that case the specimen was human, and the injection had passed in by extravasation from the ciliary processes. The injection had been made by my predecessor in Galway, the late Dr. Croker King, and the specimen which I removed from the original preparation when everting the choroid, and so brought into view, ought still to be found in the Anatomical Museum of the Queen's College there. The difficulty of applying sufficient pressure in injecting the canal of Petit directly, and the general presence of the short linear projections at the circumference, make it probable that the thread-like continuations forwards are constant structures. The canal of Petit may be described in two zones; the outer with interciliary processes, and the inner with precapsular processes.

J. C.

16.—Aberrant Artery in the lower limb.

On the left side of a male subject, dissected in the winter of 1886, a "vas aberrans" was found in the popliteal space, passing between the upper end of the popliteal artery and the upper end of the posterior tibial. The abnormal vessel was about three inches in length, and was almost a third of the thickness of the main vessel. It lay to the inside of the main artery, and at its middle was distant about half-an-inch from it. It gave off no branches. The other arteries of the lower limb were normal.

J. Y. M.

17.—Supra-condyloid Process.

In the right arm of a female subject, dissected in the winter of 1884, a small supra-condyloid process was found coupled with a high origin of the pronator radii teres muscle. The brachial artery passed behind the process, but was not, as is usually the case, accompanied by the median nerve, which lay in its normal position. In the left arm of the same subject a supra-condyloid process and a high origin of the pronator radii teres were discovered, but both artery and nerve lay in their usual position on the front of the humerus, and did not pass behind it.

J. Y. M.

18.—Extension of the Elbow Joint.

In the seventh and eighth editions of Quain's "Anatomy" there is a sentence which directs attention to the relative positions of the radius and humerus in extension of the elbow joint. It might have been better expressed, and certainly contains a clerical error, which must have escaped the notice of the editors of both editions. But the proper cure was not that which has been applied by the editor of the ninth edition, namely, to delete the sentence altogether. The fact, the allusion to which is suppressed, is curious, and the knowledge of it ought to be as general as ignorance of it appears to be. The radial surface of the humerus is directed forwards, and is invisible from behind, because its inferior edge is not prolonged round the lower end of the bone. In extension of the elbow the anterior part of the articular head of the radius is in contact with the inferior edge of the humeral surface; and the main part of the concavity on the head of the radius is separated from the humerus by a large angular gap filled up with Haversian glands. The bearing of this on the production of dislocation backwards of the radius is obvious. In fact, when a child is pulled by the hand in the manner alluded to by Chelius as frequently producing this dislocation, not even the anterior edge of the radius is in perfect contact with the humerus.

As respects the position of the ulna in full extension, it is curious to note that the pressure of the olecranon is not, as might be supposed, against the deep part of the olecranon fossa. That is to say, it is not against the thin bone sometimes converted into a foramen, but against a spot on the inner side of the outer pillar of bone bounding the fossa. A distinct facet can sometimes be seen on the dry humerus at this spot, but it is not covered with cartilage in the recent state. The part of the olecranon brought into contact with it is the outer portion of the upper margin of the articular surface, and in part overhangs that elongated facet on the outside of the olecranal articular surface which gradually glides into complete contact with the humerus as the elbow is extended after being bent at a right angle. The same arrangement appears to be found in mammals generally, and is very distinct in the hare.

J. C.

19.—Pronation and Supination.

I may further point out that the head of the radius presents a semilunar convexity in front of its shallow concavity. In movements of pronation this convexity articulates with the groove on the humerus internal to the capitellum, and in complete pronation lies behind, away from the humerus altogether. The diameter of the head of the radius backwards from the middle of this convexity is distinctly greater than the diameter at right angles to the first, and as the orbicular ligament binds the radius closely, it can be seen to be displaced outwards and inwards at the outer part according as the long diameter of the head of the radius is lying transversely or antero-posteriorly. Thus, in pronation, when the styloid process of the radius moves circularly inwards, the concavity of the head of the radius is pushed outwards, and consequently the apex of the cone described in pronation and supination is not situated on the humeral surface of the radius, but a little lower down. Therefore no point of the radius remains in contact with any one point of the humerus in any movement of pronation or supination.

J. C.

20.—The Vertebral Artery of the Common Seal (*Phoca vitulina*).

In the paper on the "Arterial System of Vertebrates homologically considered" I have described and figured the arrangement of the vertebral artery of the Hooded Seal (*Stemmatopus cristatus*), and pointed out the similarity which it presents in some points of its distribution to the vertebral artery of the Crocodilini. In the Common Seal this peculiarity in the anatomy of the vessel is even more marked.

The vertebral artery arises from the subclavian and divides, almost immediately, into two large vessels. One of these passes forwards through the transverse processes of the cervical vertebræ in the usual manner. The other is directed backwards, and, entering between the neck of the first rib and the transverse process of the first dorsal vertebra, continues its course above the rib necks and below the transverse processes and joins, in almost undiminished size, the trunk of the first aortic intercostal artery which passes along the sixth interspace. The supply of the five higher intercostal spaces is provided by the anastomotic trunk.

J. Y. M.

21.—Facets of Rest in the Elbow-joint.

In the case of the elbow-joint, not only is there a small surface on the olecranon which rests on a special spot at the outer side of the olecranon fossa of the humerus (as described above by Professor Cleland), but there is also on the inner edge of the coronoid process a small notch, generally covered by articular cartilage, which in full flexion is pressed against the inner pillar bounding the coronoid fossa. The exact part of the humerus with which this notch on the coronoid comes in contact is in a fresh specimen marked by the opaque whiteness of the fibrous tissue covering the bone, and in the dry bone by a slight depression.

The outer edge of the coronoid process also rests on the corresponding pillar of the coronoid fossa in full flexion, but the pressure here is never so great as to produce a notching of the bone.

In full flexion, as in full extension, the ulna and the humerus come into contact, but the pressure is borne by the sides of the projecting processes of the ulna and the pillars bounding the fossæ of the humerus, and not by the beaks of those processes and the thin plate of bone separating the fossæ. In accordance with the obliquity of the plane of movement relatively to the shaft of the humerus, the pressure between the bones is greatest at the outer side of the joint in extension, at the inner side in flexion.

The surface on the olecranon and the notch on the coronoid are facets of rest only coming into play at the extremes of movement. The presence of such facets as a distinct element in the mechanism of joints was first distinctly recognised by Goodsir, who called them "terminal facets," and stated "that they existed in all diarthrodial articular surfaces" situated at the opposite extremities of the lines of movement (Goodsir, *Anatomical Memoirs*, II., 236).

R. B. Y.

21.—The External Semilunar Cartilage as a Complete Disc.

Three instances of this peculiar development of the external semilunar cartilage came under my notice in the dissecting-rooms here during the winter session, 1886-7. In each of these cases, while the internal semilunar cartilage was normal, the external was not semilunar, but formed a complete disc interposed between the condyles of the femur and the tibia, so that their articular surfaces never came into contact in any position of the joint. Between the anterior and posterior attachments of the cartilage, and just over the top of the external tubercle of the tibial spine, there was a small gap about quarter of an inch square, but even here there was no contact of the articular surfaces.

In two of the cases in which the markings on the femur were observed, the inner part of the outer groove separating the patellar from the menisco-tibial surface was not marked, though the outer part of that groove was distinct. The explanation of this is that, while the outer part of the groove was caused in the usual way,* the part of the anterior and inner border of the tibia, which in normal circumstances comes in contact with the femur at the close of extension, and so gives rise to the inner part of the outer groove, was prevented by the interposition of the complete inter-articular disc from doing so in these cases.

The occurrence in the human subject of a complete cartilaginous disc between the surfaces of the external condyles of the femur and the tibia, taken along with the fact that in the crocodile the inter-articular cartilages of the knee-joint form complete plates separating the articular surfaces of the bones, seems to me worthy

* See p. 149 of this vol.

of note as pointing to their perhaps having some higher morphological value as separate elements in the knee-joint than is attributed to them by Mr. Sutton in his very interesting papers on the ligaments.*

R. B. Y.

23.—Additional Note on Birds with Supernumerary Legs.

My memoir on this subject was read before the Philosophical Society of Glasgow on 3rd February, 1886, and published in the *Proceedings* of the society that summer. In April of the same year there appeared an account of a "Supernumerary Leg in a Male Frog," by Dr. Tuckerman, in the *Journal of Anatomy and Physiology*, with an editorial note by Sir William Turner; and in January, 1887, in the same journal there was published a paper "On Some Monstrosities in a Dorking Fowl," by Dr. A. M. Paterson. It is true that none of these three writers have had the faintest notion of the true nature of the monstrosities of which they have written, and in that respect they are just in the same position as other authors. But Dr. Tuckerman's frog is interesting as an amphibian exhibiting precisely the same class of abnormality as that which I have explained in birds and in man. The added limb was clearly of composite nature, and arising to the left of the developed termination of the spinal column. Sir William Turner happened to be right in comparing it with the case of dos Santos, though evidently unacquainted with the *rationale* of either case, and with the common occurrence of similar phenomena in birds. Dr. Paterson also, while curiously enough referring to Dr. Tuckerman's paper and Sir William Turner's remarks as the only literature bearing on his specimen, and yet failing to see the relationship to it of the frog's additional limb or that of dos Santos, furnishes an interesting account of a partial development of a third cæcal pouch. I have given examples of four cæca and of three cæca, but Dr. Paterson's specimen had the peculiarity that, while one cæcum was normal, the other was double at its extremity, and also for some distance in the middle of its course.

I regret that when I wrote my memoir I was unacquainted with the remarkable work of Otto, "Monstrorum Sexcentorum Descriptio Anatomica," Vratislaviæ, 1841. In that work (pp. 258-264) Otto records no fewer than twenty-five instances of birds

* *Jour. of Anat. and Phys.*, April, 1885, p. 253; and "Ligaments, their Nature and Morphology."

with supernumerary limbs beneath the tail which he had himself collected, and in eleven of them he expressly notes more or less visceral duplicity. In one instance the duplicity of the alimentary canal was complete from the point of attachment of the vitelline duct back to two separate cloacæ. In eight instances there were two cloacal orifices. In only one instance do I find that he notes the presence of three cæca, but it seems very possible that in other cases the cæca had not been examined. Four other instances of supernumerary limbs in birds, in which the appended limbs hung from the chest, chest and abdomen, or the side, are described by Otto; but the different nature of the two kinds of duplicity did not come under his notice, for all the twenty-nine cases are included in one group of monsters, "Monstra ex inæqualibus congenita." In accordance with the failure to discover the true nature of subcaudal limbs is the circumstance that, while he figures a beautiful example of a coot with two fully-formed additional feet projecting behind, he has not noted the sides to which the additional feet belong.

Two additional examples have come under my own notice since I wrote my memoir. One was a drake with two cloacæ, each surmounted by a penis, and the single intestine was furnished with three cæca. The additional limb in this instance had a single stem and divided into two widely separate feet. It sprung from between two pelvic bones intruded on the left side of the tail, and so well developed that there was no difficulty in distinguishing their parts and ascertaining that the right one was to the left side of the right one. The other specimen was a hen; the pelvic part of the additional limb was minute and free, and the limb ended in one toe; there were two cloacæ and three cæca.

A comparison of different specimens shows that the degree of development of additional pelvic elements, and the closeness of their connection with the main skeleton, vary quite independently of the degree of development of the additional feet; also, that the degree of duplicity of the alimentary canal is not regulated by the degree of development of either pelvic or distal elements of the added limbs.

I cannot leave this subject without making a suggestion as to the cause of the uniformity with which total disappearance is effected of one of the divisions of the vertebral column. The key to that is to be found in the circumstance that two limbs originally belonging to different divisions of the embryo adjust themselves to form a normal pair. Individuality is not indefinitely pre-existent, but is an evolution, and the forces, whatever they are, which bring it about may be said to aim at its completion even in abnormal circumstances, and in those circumstances to evolve unusual methods. I suppose that it is to the tendency to the production of a complete normal bird that we must attribute the withdrawal of nutrition from one division of a vertebral column which, beyond all question, was at an early age bifurcated. No doubt, after the division of the growing point of the germinal mass into two columns, instead of its continuing a single column backwards, there is no tendency to the suppression of adjacent halves of the primordial columns so as to bring the outer halves together. The vitality of the adjacent sides shows itself, in those instances in which two equal bodies are formed, to be equal to that of the outer sides, and the hypothesis is that it is such an equal division which has originally taken place. But, plainly, the outer leg of the suppressed division of the body exchanges its dependence on the individuality of that division for dependence on the other division, taking to itself, in fact, the just office and relations of the corresponding supernumerary limb; and after this has taken place we have no longer to do with two similar divisions of the body, with similar potentialities.

Probably the first thing to happen is that owing to the position of bifurcation the proper development of pelvic limbs in the bifurcation is interfered with. The next thing to happen is probably that the limb-blastema in the bifurcation, in its efforts to grow, presses on the parts around, and that one division of the column succumbs, while the other is enabled by that circumstance not only completely to resist the pressure made on it by those limbs, but to draw the furthest-off limb toward itself, and thereby more or less completely extrude the intervening limbs in a backward direction.

Difficulty there certainly is in trying to investigate such procedures, but it is instructive to note how in such teratological problems there is no eluding the action of forces which are neither chemical nor mechanical, and are altogether unparalleled in the inorganic world. In proof of the tendency of abnormally-altered embryos to return to a normal state I may point to the comparative frequency of healthy twins in one set of membranes, and therefore derived from one ovum, and the infrequency of incomplete separation, such as was exhibited by the Siamese twins; also to the presence of a healthy child along with an acephalus.

J. C.

24.—Structure of Tendon.

Having had occasion, at the recent meeting of the British Medical Association in Glasgow, to exhibit some specimens of tendon from the rat's tail and from various large tendons of the human limbs, I think it well shortly to note the results of my observations as far as I have yet gone. While Ranvier discovered the quadrate scales associated with his name, Boll described a longitudinal keel on the back of each scale. No such keel exists. What lies on the back of the scale is an elongated nucleus. The nucleus of the scale in the rat's tendon is circular and flat; but the nuclei of which I speak are cylindrical, each as long as the quadrate scale in front of it, and united by a thin thread to the nucleus in front and the nucleus behind, so that a chain is formed. These cylindrical nuclei in human tendons are large sausage-looking bodies deeply stainable with carmine. While within the grasp of the quadrate scales there is only the white substance which forms the main mass of the tendon, a variety of connective tissue elements may be found on the other side.

J. C.

25.—The Ligamentum Nuchae in Rhea Americana.

In the lowest five cervical vertebræ of this bird the spinous processes are bifid, and between the lips of those bifid spines there is a groove in which the ligamentum nuchae lies. In the case of the lowest cervical spine the groove is about three-eighths of an inch deep; above this it gradually diminishes in depth, ceasing to be marked above the fifth lowest cervical, though traces of it are to be found as high as the eighth. The ligament arises from the spine of the first dorsal as a strong rounded cord of elastic fibres. Passing upwards it is bound down into the furrow formed by the bifid spines by a fibrous sheath attached on each side to the lips of the groove. The canal thus formed for the ligament is lined by synovial membrane.

When the fibrous covering closing in the groove is cut through, the ligament is set free and is found to consist of an undivided portion extending from its origin upwards for about an inch and a half. The ligament then divides into a series of slips running to be attached from the fourth as high up as the ninth lowest cervical vertebra.

The strong elastic ligament accommodated in this synovial canal can work freely in supporting the long cervical column without destroying its contour by raising a fold of skin, as it must have done had the fibres passed straight across the concavity of the curve in the lower part of the neck.

R. B. Y.

26.—Absence of the Subclavius Muscle.

Absence of this muscle seems to be rare. In Macalister's paper on "Muscular Anomalies" (*Trans. Royal Irish Acad.*, vol. xxv., p. 51), the only instance referred to is that recorded by Gruber as having occurred on the left side in a monstrous fœtus (*Virch. Arch.*, vol. xl., p. 430). Last winter I came across a female subject in which the subclavius was absent on both sides. Its place was taken by fibrous tissue, continuous on the inner side with the costo-clavicular ligament, on the outer with the costo-coracoid membrane.

Sutton (*Ligaments, their Nat. and Morph.*, p. 68) holds that the costo-clavicular ligament "arises from regression of the sternal fibres of the subclavius," and Cleland points out how the position of the subclavius in relation to the costo-clavicular ligament and the costo-coracoid membrane "suggests an important ligamentous function of that muscle" (*Lancet*, 1881, vol. i., p. 283).

The state of matters in the present case is therefore very interesting, as showing on the one hand complete "regression" of the fibres of the subclavius, while on the other, the replacement of that muscle by fibrous tissue continuous with the costo-clavicular ligament and the costo-coracoid membrane goes to prove the ligamentous action of the muscle in restraining along with these bands the upward movement of the clavicle at its outer end.

I have quite recently seen a case illustrating a transition stage in the disappearance of the subclavius. In this subject, an adult male, the muscle was on each side reduced to a very slender band, consisting only of a few fibres.

R. B. Y.

27.—Post-anal Dimple.

The only instance of post-anal dimple that I have seen was in an adult female subject in the dissecting-rooms here. In this case there was a well-marked dimple just over the tip of the coccyx. It led to a narrow blind pouch which admitted a probe for a short distance. The sacrum, which was afterwards examined, was straight, as in the adult case described by Cleland. (*Jour. Anat. and Phys.*, xvii., p. 290.

In the same place are described two cases of post-anal dimple in monstrous fœtuses, and the view is put forward that it is due to arrest of growth in the notochord.

R. B. Y.

28.—Additional Note on Abnormality of the Intestine.

Through the kindness of Dr. Coats I have, since finishing the paper on "Development and Abnormality of the Intestine," published in this volume, had an opportunity of examining an interesting arrangement of the intestine in a female child three years of age. In this case the descending colon and left half of the transverse were attached to the abdominal wall by a free meso-colon. The portion of the great intestine representing the ascending colon and right half of the transverse lay on the right side of the abdomen, with the cæcum in the region of the right iliac fossa, and together with the whole of the small intestine as far as the upper end of the jejunum formed a loop hanging quite free in the abdominal cavity, save for the narrow peritoneal attachment between the transverse colon and the duodenum at that point where the neck of the primary loop was.

Some time after seeing this case I noted in the dissecting-room an exactly similar state of matters in an adult female, and, on looking over Treves' memoir on the "Intestinal Canal and Peritoneum," I find that at p. 54 he records the occurrence of such a free loop of intestine in two adult subjects. These facts show that this abnormality is not very uncommon. The resemblance of the different cases in their characteristic features is striking, the more so when it is borne in mind that exactly this arrangement of intestine is normal in many of the lower animals.—(See Cleland's figure of the intestine in the wombat, *Journal of Anatomy and Physiology*, 1870, pl. viii.)

Further, as I have pointed out (p. 83 of this volume) the intestine, at that stage of development when the twist to the right has just occurred, is disposed exactly as in those abnormal cases, while according to the view usually held as to the transit of the cæcum there is no stage which so corresponds. These cases are therefore simply instances of the persistence of a stage in the development of the intestine, which is permanent in some of the lower animals.

R. B. Y.

29.—Unusual Course of the Phrenic Nerve.

The subject was an adult male. The phrenic nerve on the right side passed downwards in front of the great nerve-cords quite outside of the border of the scalenus anticus muscle till it reached the transverse cervical artery, which in this case was given off by a trunk springing from the third part of the subclavian, just beyond the border of the scalenus anticus. The phrenic then passed round behind the transverse cervical artery, bent abruptly inwards, and, crossing the scalenus anticus, entered the thorax. The phrenic thus looked exactly as if it had been hooked to the outside of the scalenus by the artery. Where it turned round the transverse cervical artery it lay quite close to the third part of the subclavian. The filament connecting the phrenic with the fifth cervical nerve was present, as well as the usual larger root of the nerve.

The very short trunk coming off from the third part of the subclavian, besides giving off the transverse cervical, also gave origin to the suprascapular and the ascending cervical arteries. The ascending cervical ran upwards outside the border of the scalenus anticus parallel and internal to the phrenic nerve. The internal mammary artery came off from the third part of the subclavian, and, turning inwards, descended to the thorax. The inferior thyroid arose from the first part of the subclavian.

A similar case is recorded in *Quain's Anatomy of the Arteries* (p. 140). The abnormalities in that case occurred on the left side, but otherwise are very like those described, the course of the phrenic nerve being the same as in the present case, and the transverse cervical, ascending cervical, suprascapular, and internal mammary arteries all arising from the third part of the subclavian.

In another case, described by Koster (Analytical Notices by Moore in the *Journal of Anatomy and Physiology*, 1870, pp. 338-9), the phrenic nerve ran down outside of the scalenus anticus, curved behind the transverse cervical and the suprascapular arteries, and then turning inwards and lying in front of the subclavian vein passed into the thorax. The explanation given of the abnormal position of the phrenic in that case is that the nerve arose high up (there was no connection with the fifth cervical), and separating later than usual from the supraclavicular nerves followed the course sometimes taken by fibres of the nerve coming from the third cervical (*Cf. Luschka, Anatomie,* vol. i., p. 410).

I need scarcely direct attention to the dangers which such an arrangement of parts as existed in these cases would present to an attempt at ligature of the third part of the subclavian.

R. B. Y.

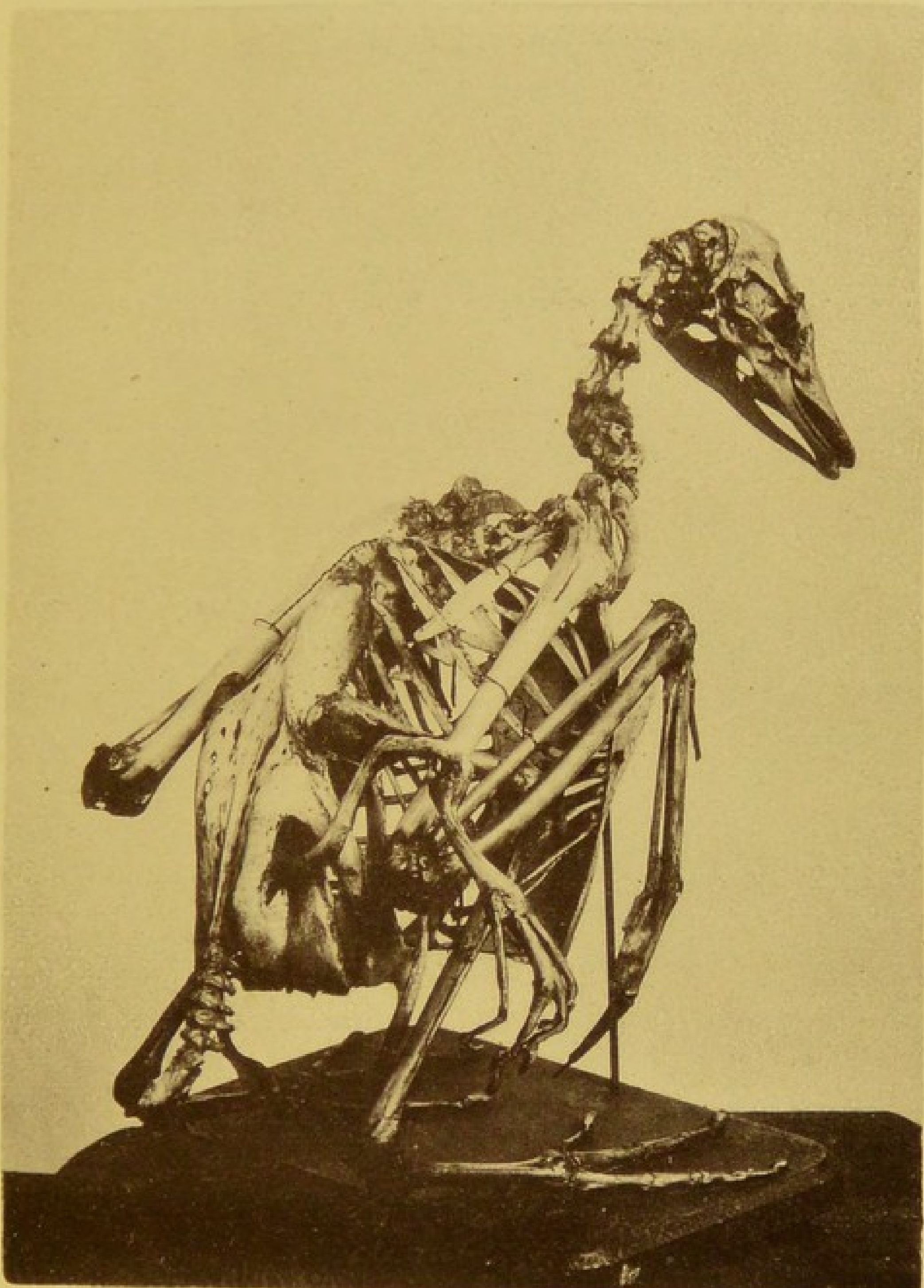


Fig 1.

Maclure & Macdonald.

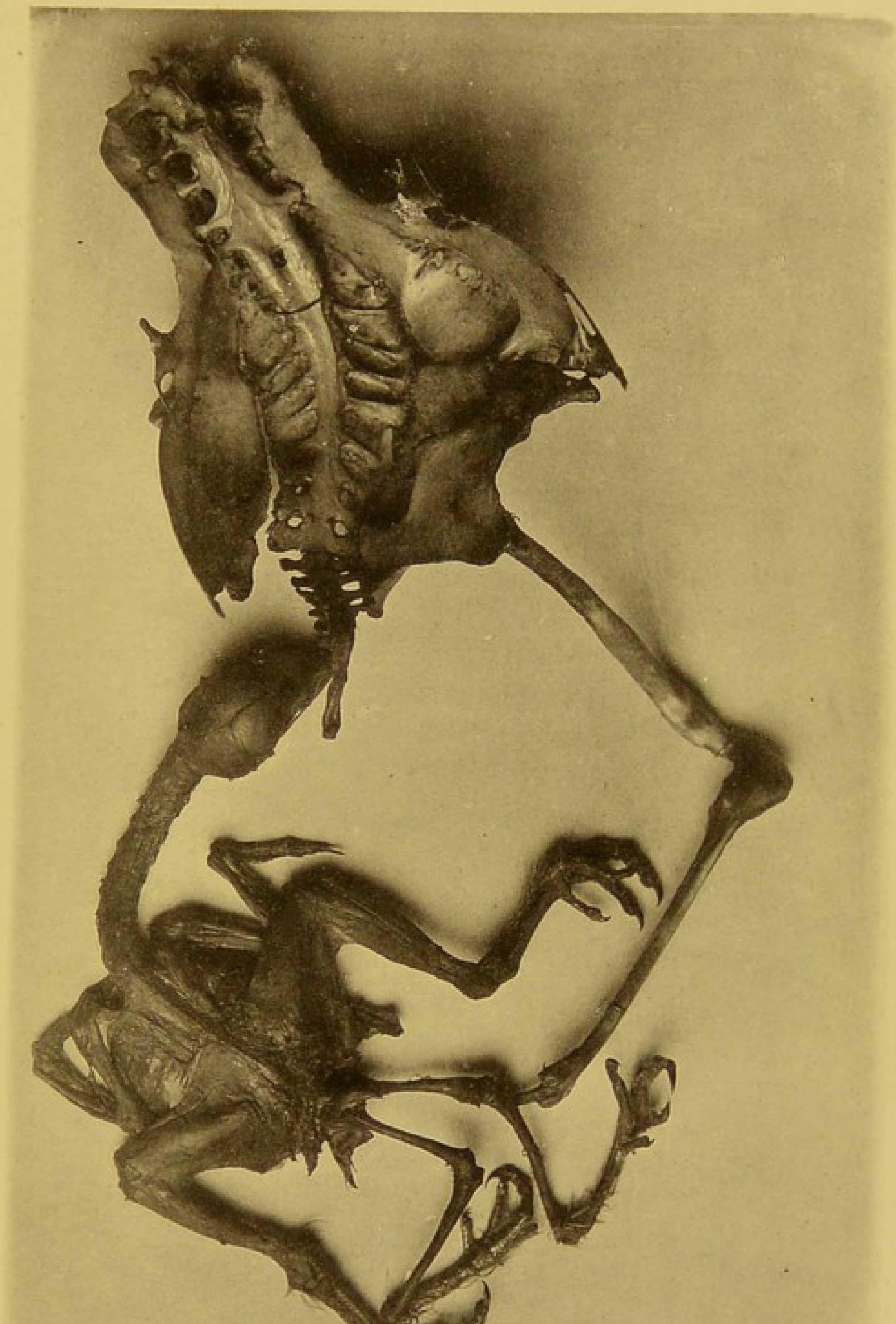


Fig. 2.

Fig. 3.

Maclure & Macdonald.

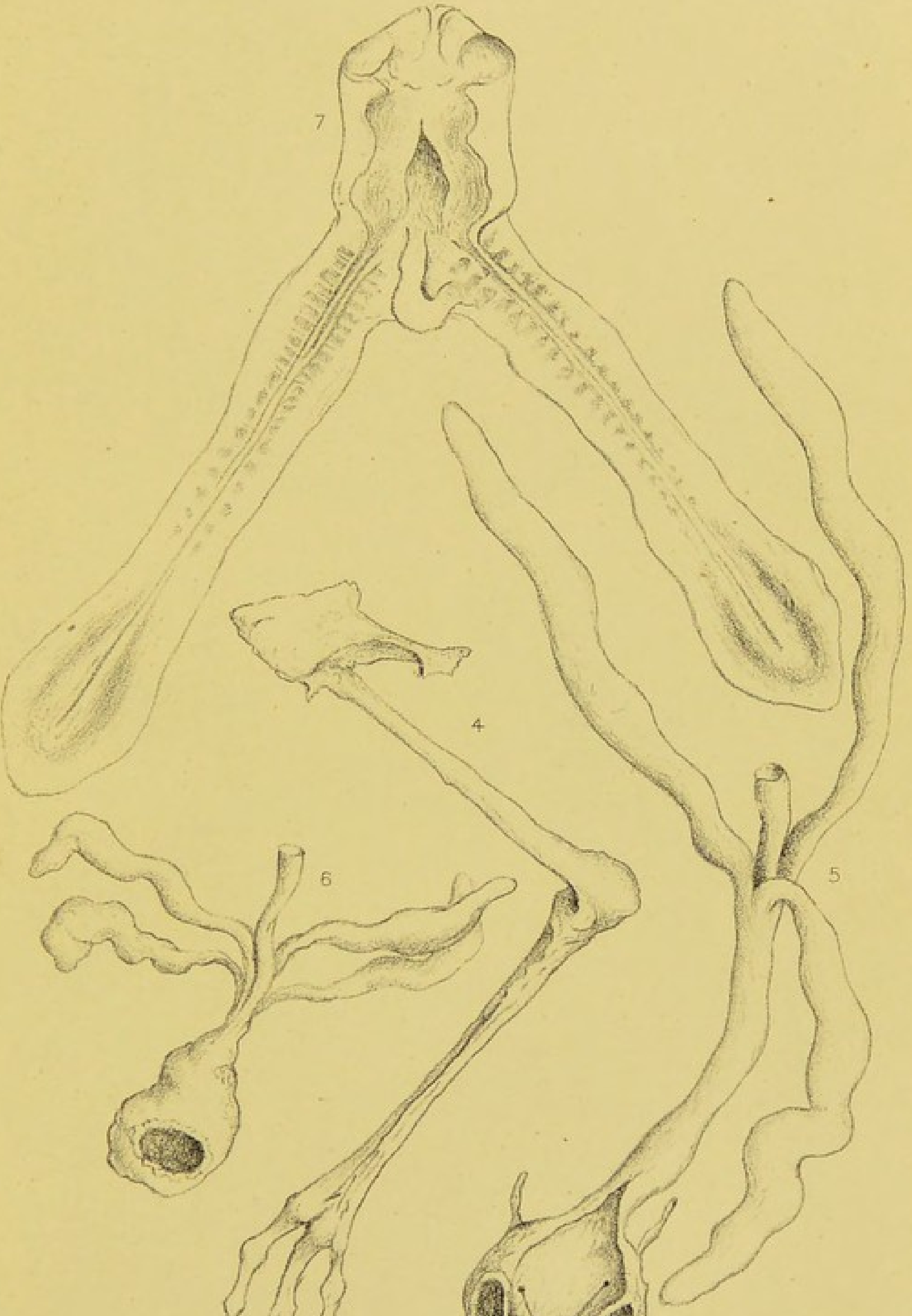


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Plate IV

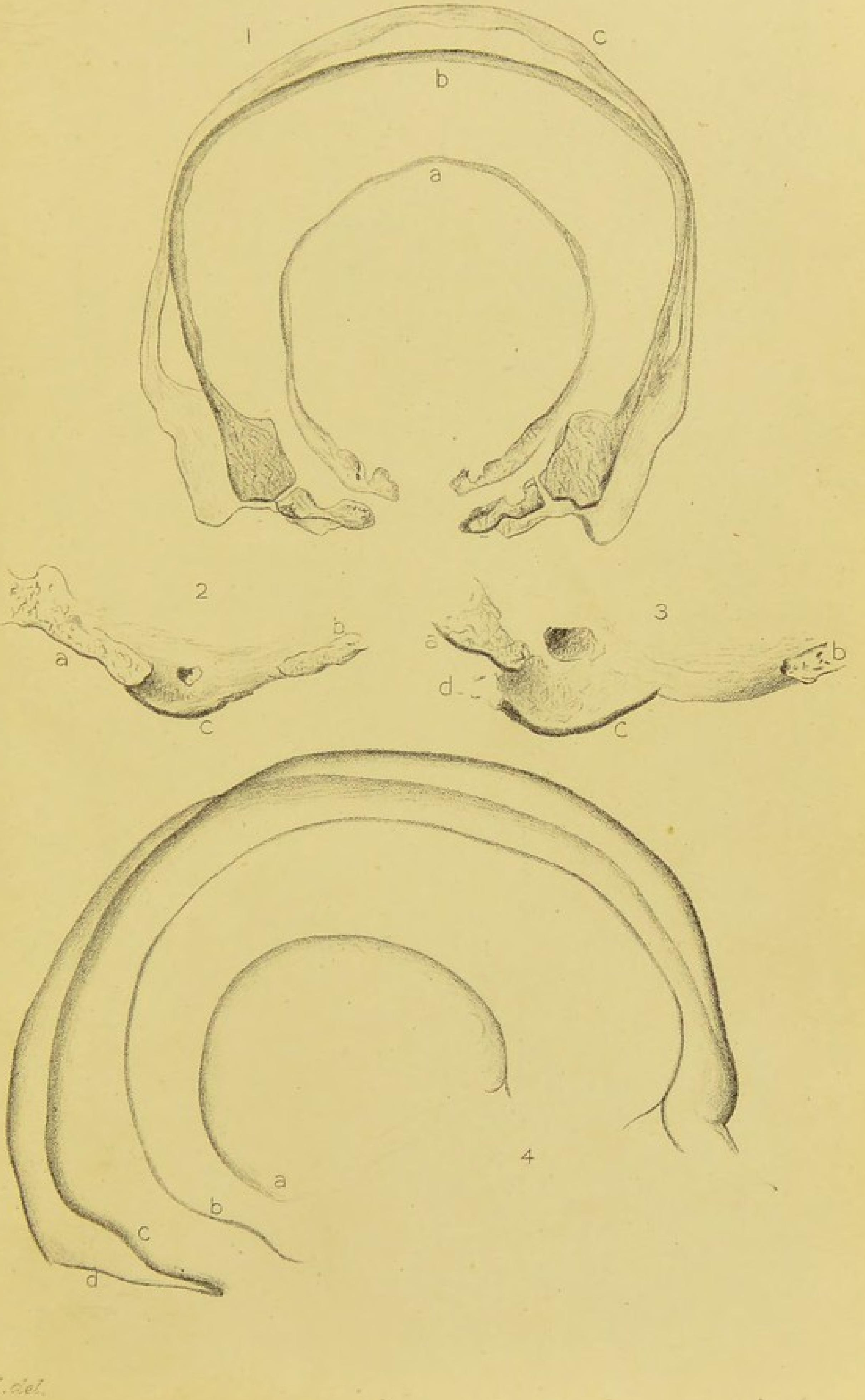

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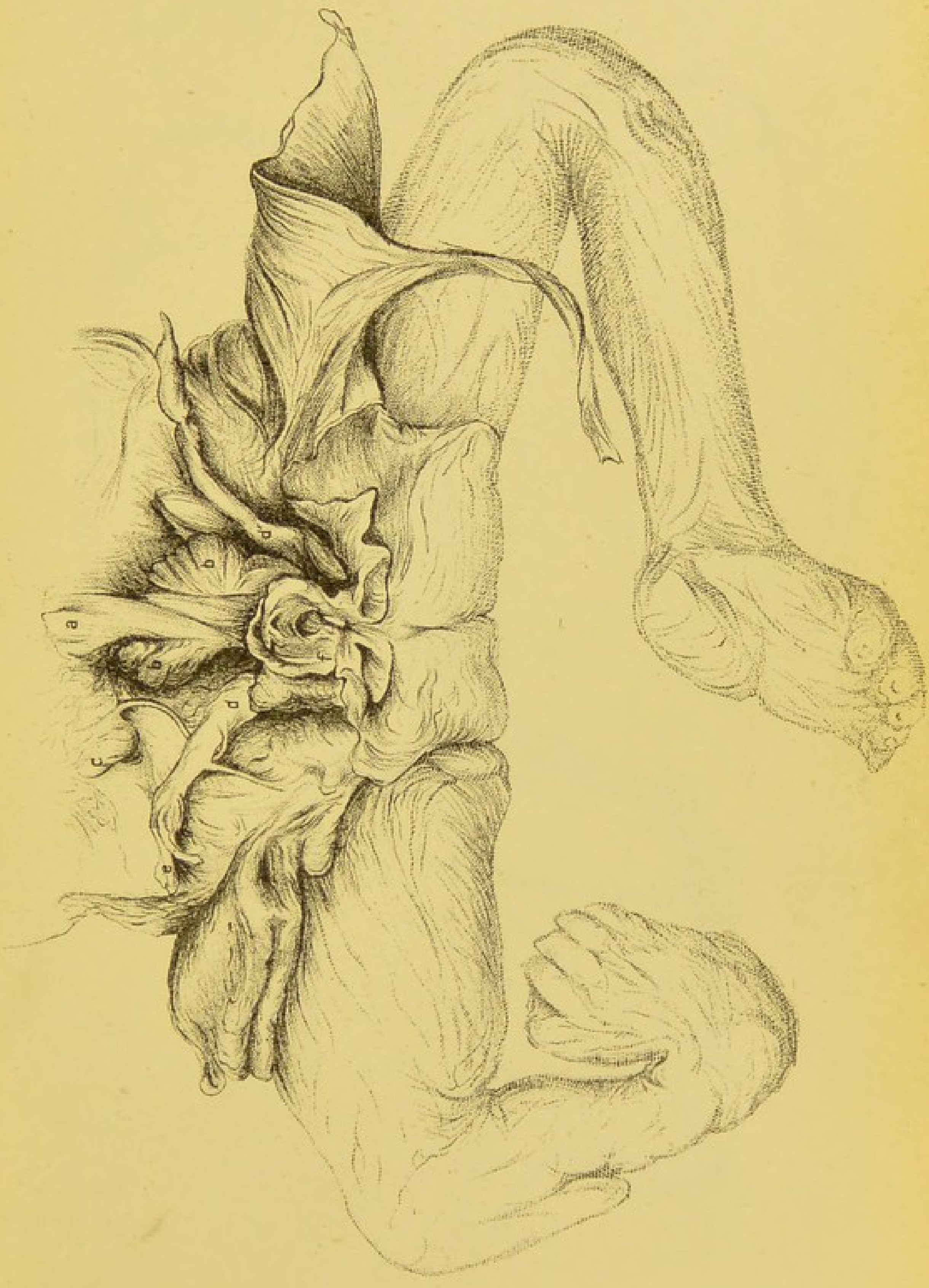
Plate V.



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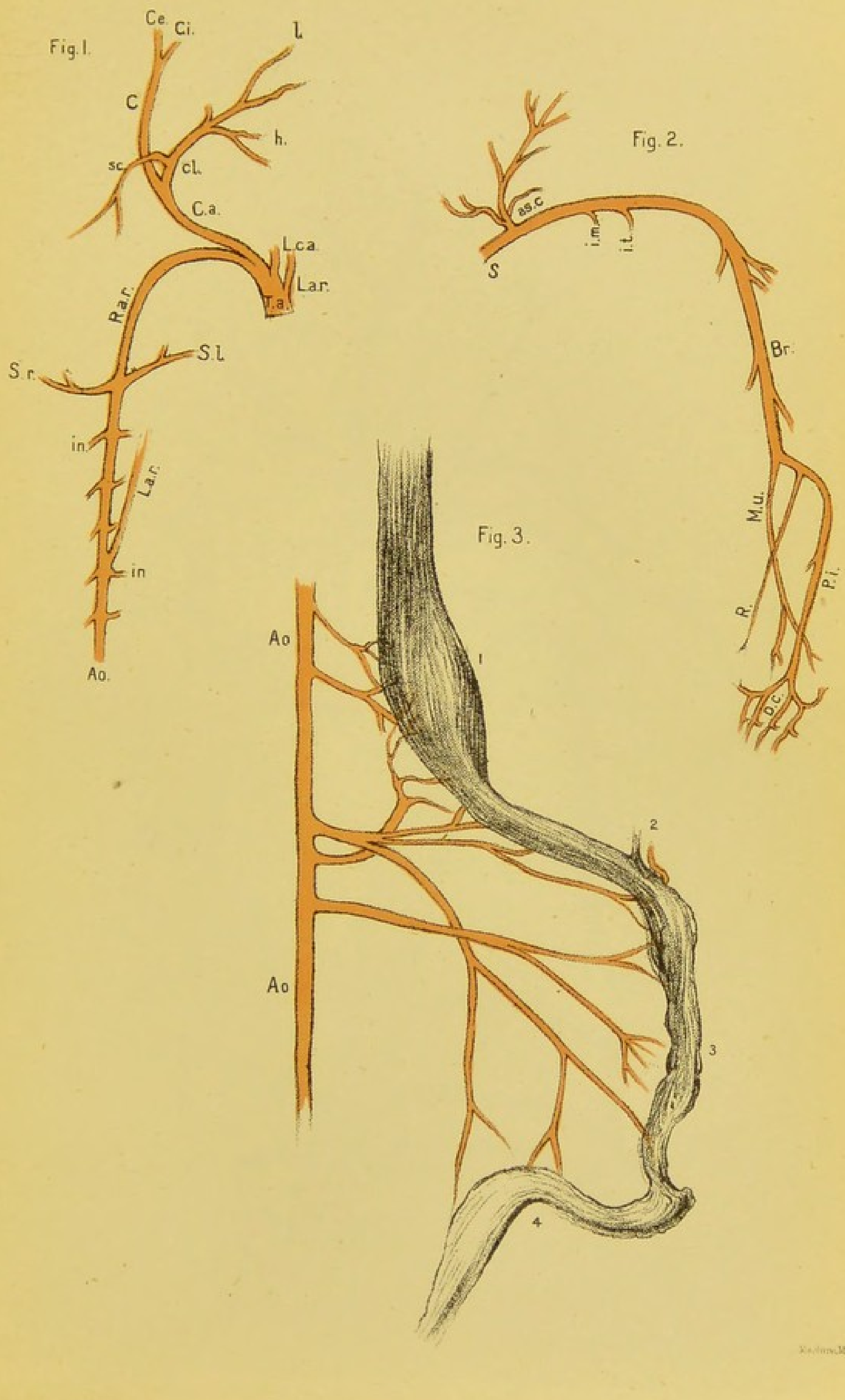
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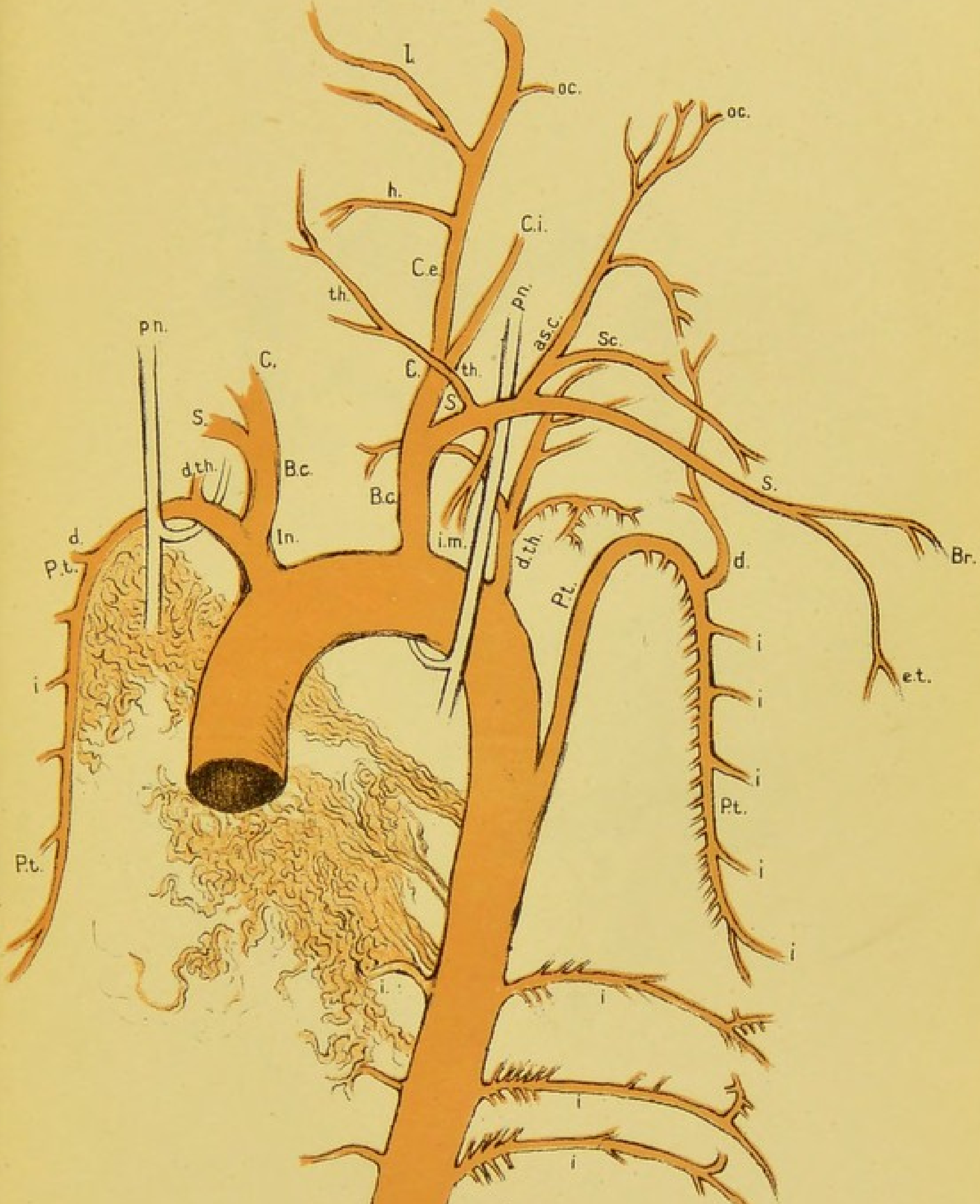

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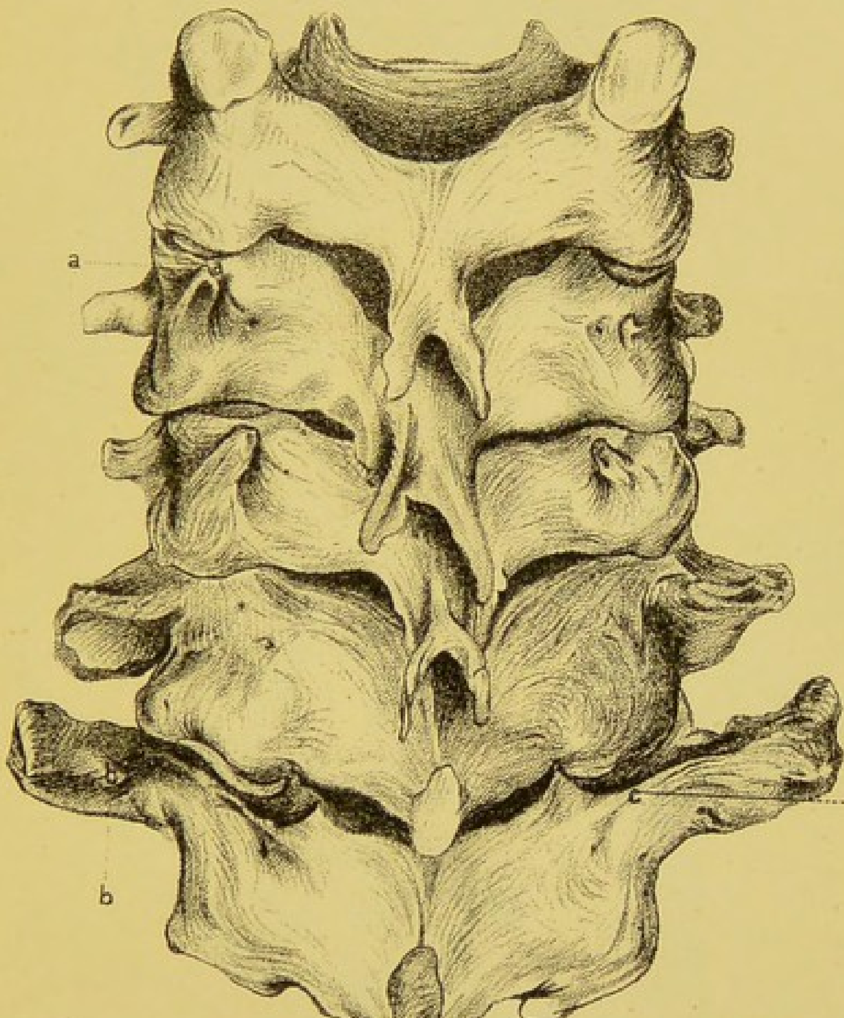

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Plate IX

Fig. 1.

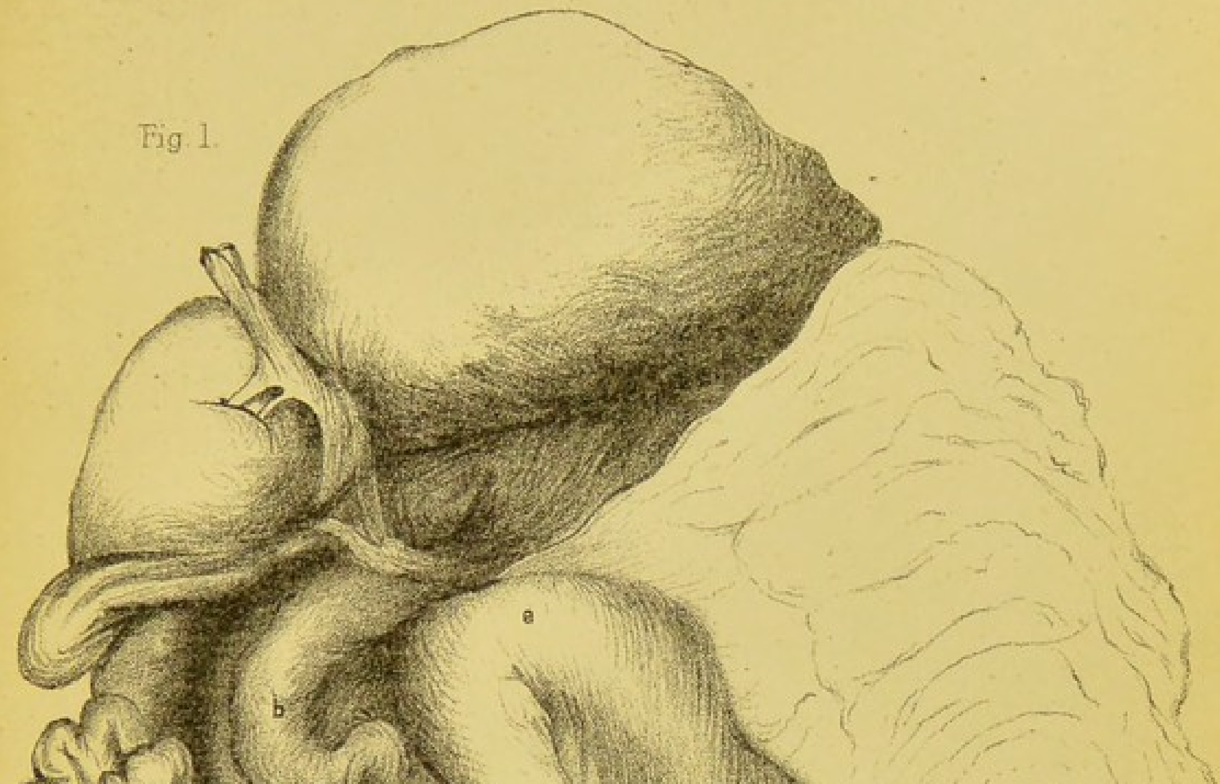

Fig. 2.

Fig. 3.

Maclure, Macdonald & Co.

Plate X.

Fig. 3. Fig. I.

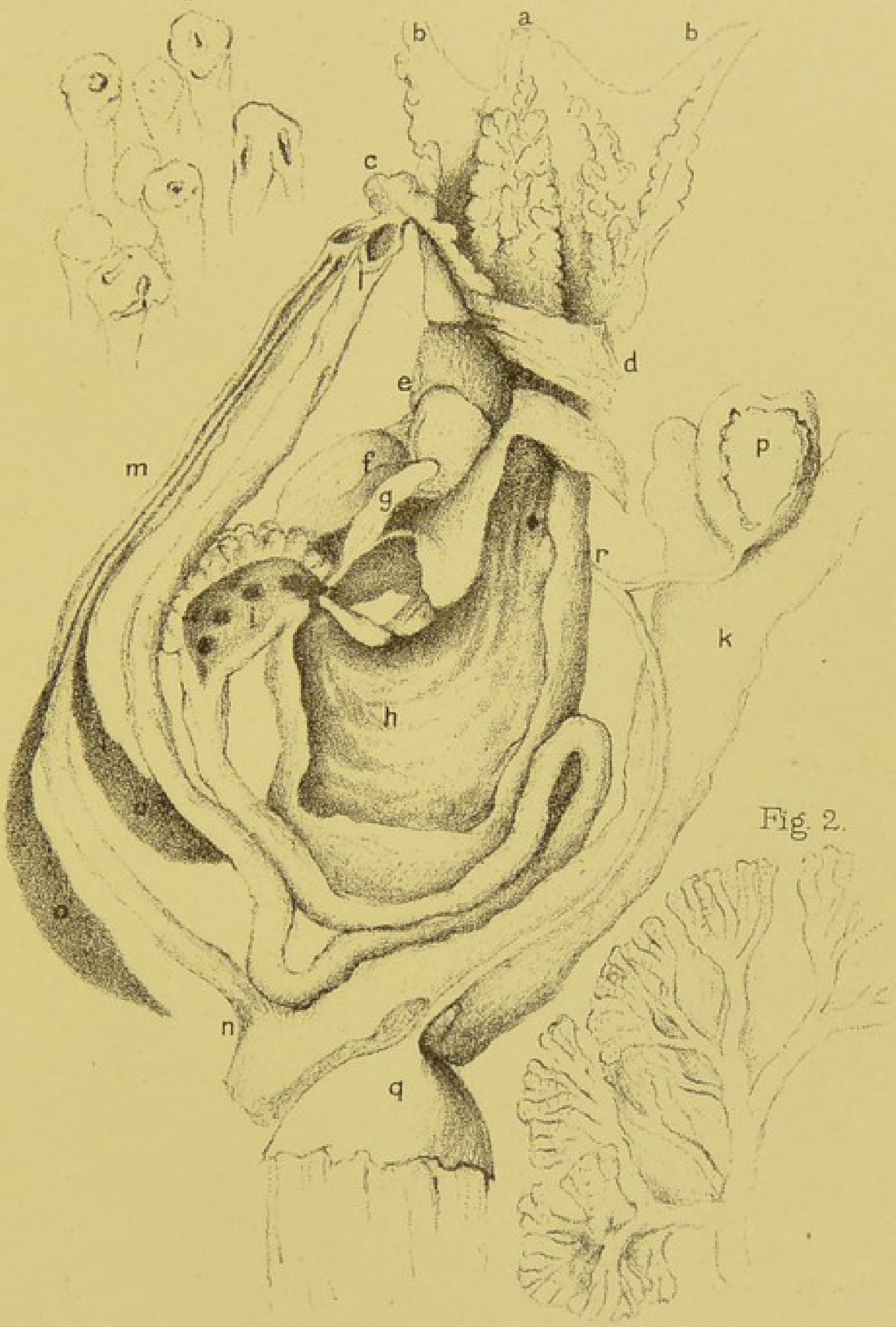

Fig. 2.

Maclure, Macdonald & C°

Plate XI

Fig. 5.

Fig. 1.

Fig. 4.

Fig. 2.

Fig. 3.

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Fig. 1.

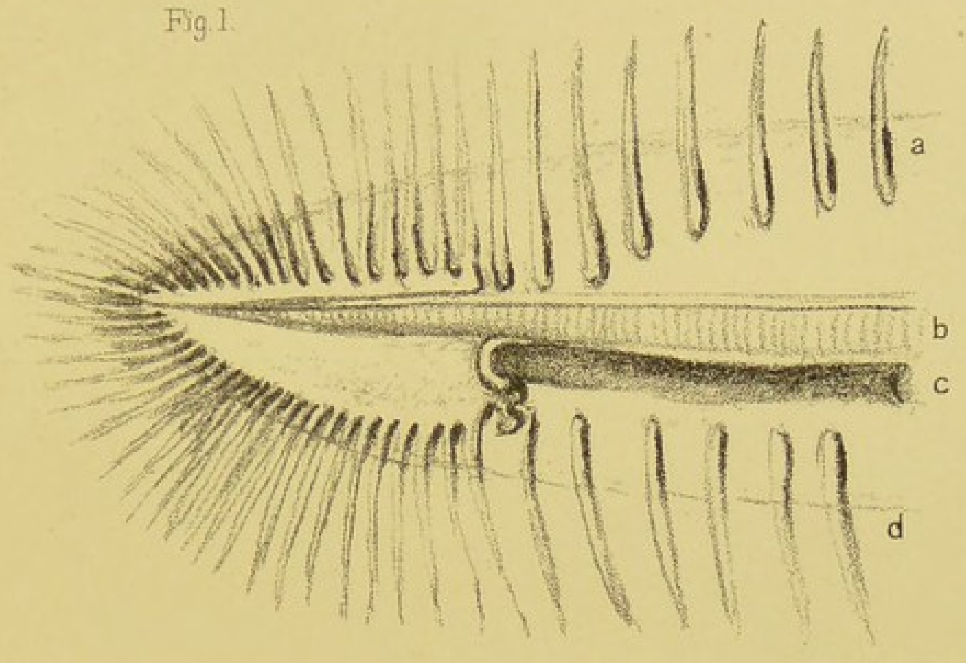

Fig. 2.

Fig. 3.

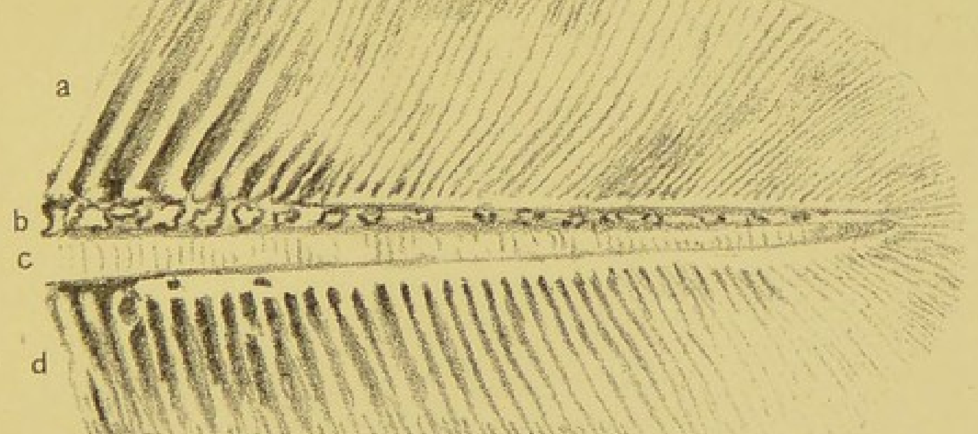

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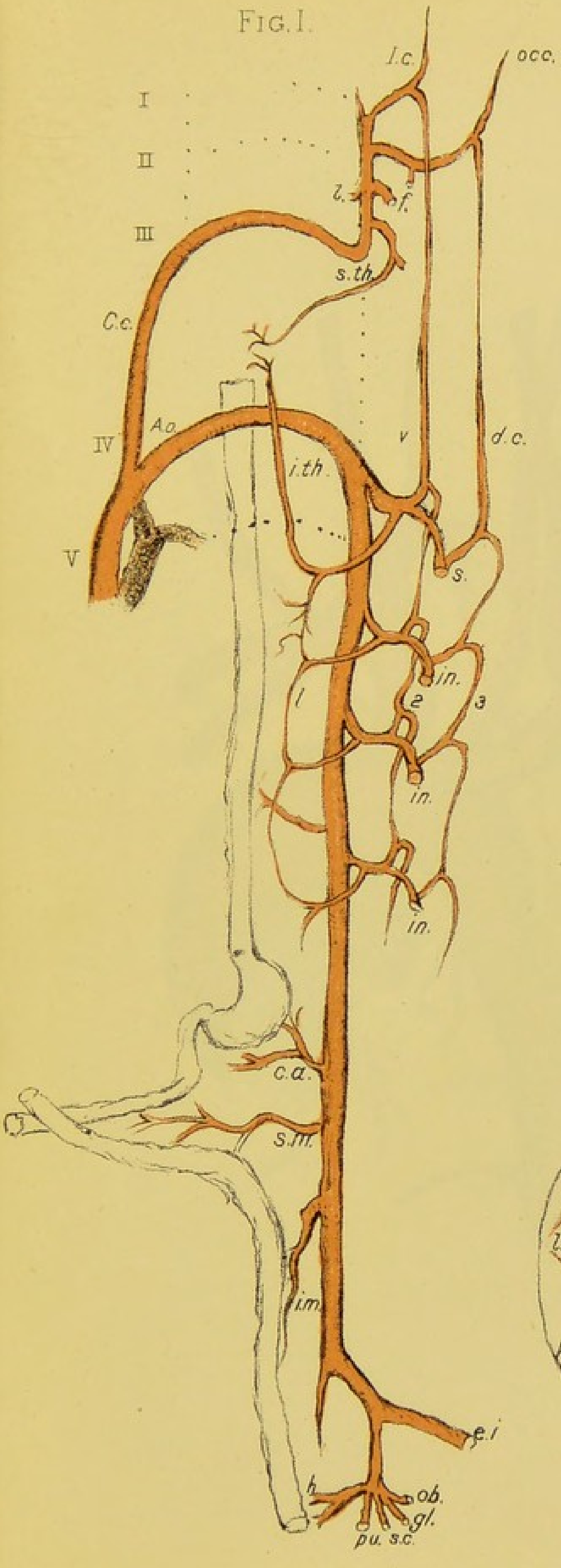
Fig. I.



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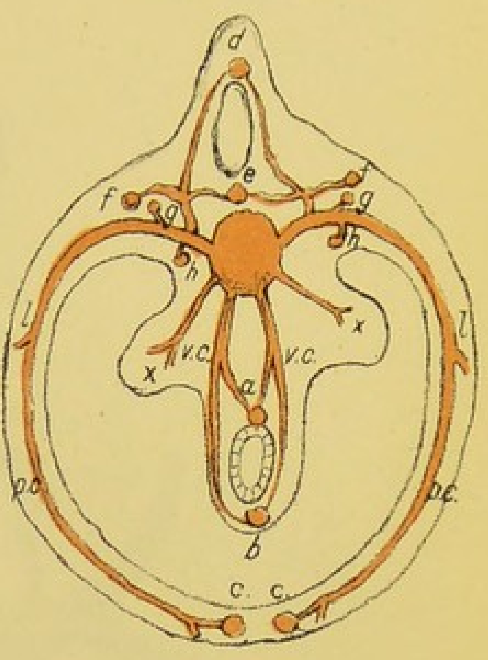

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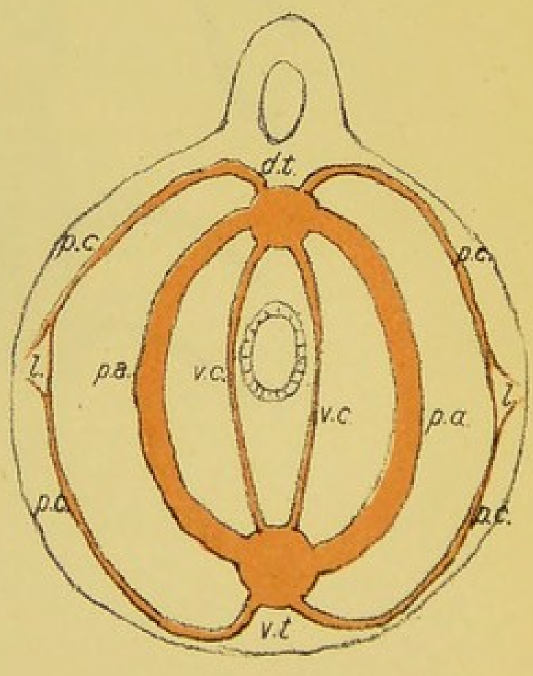

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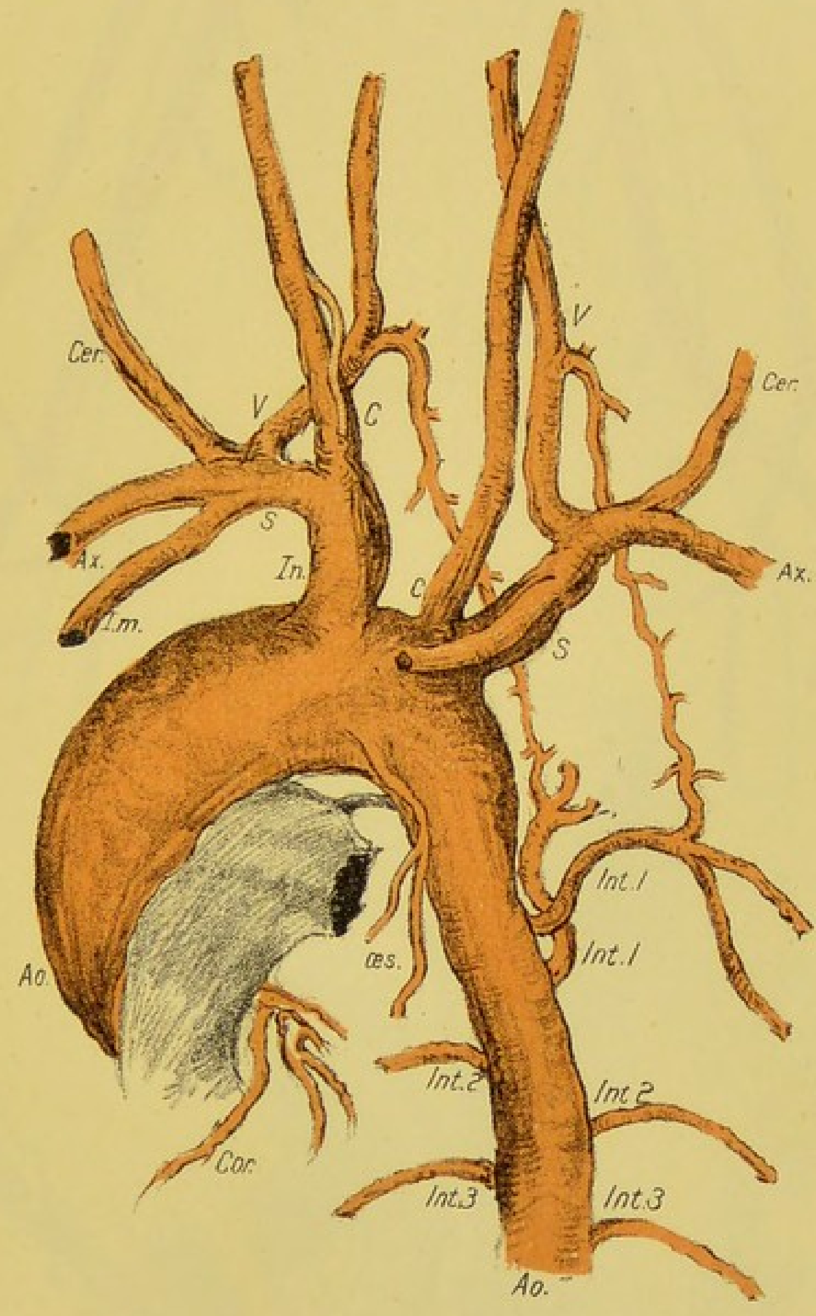

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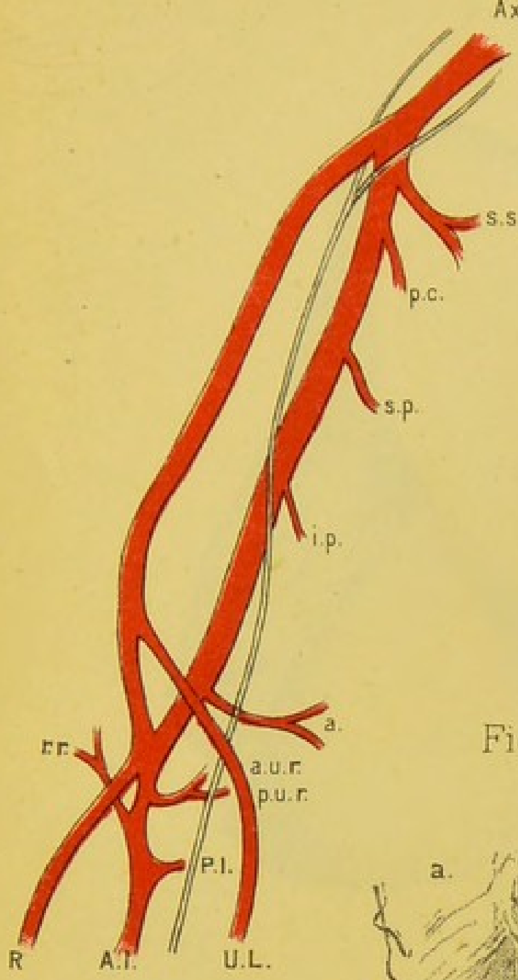

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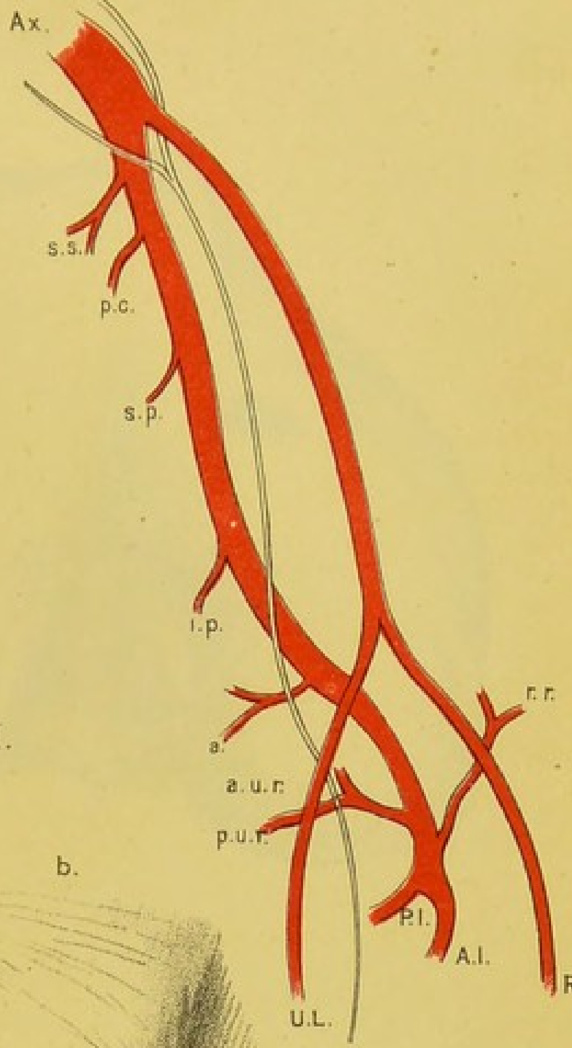

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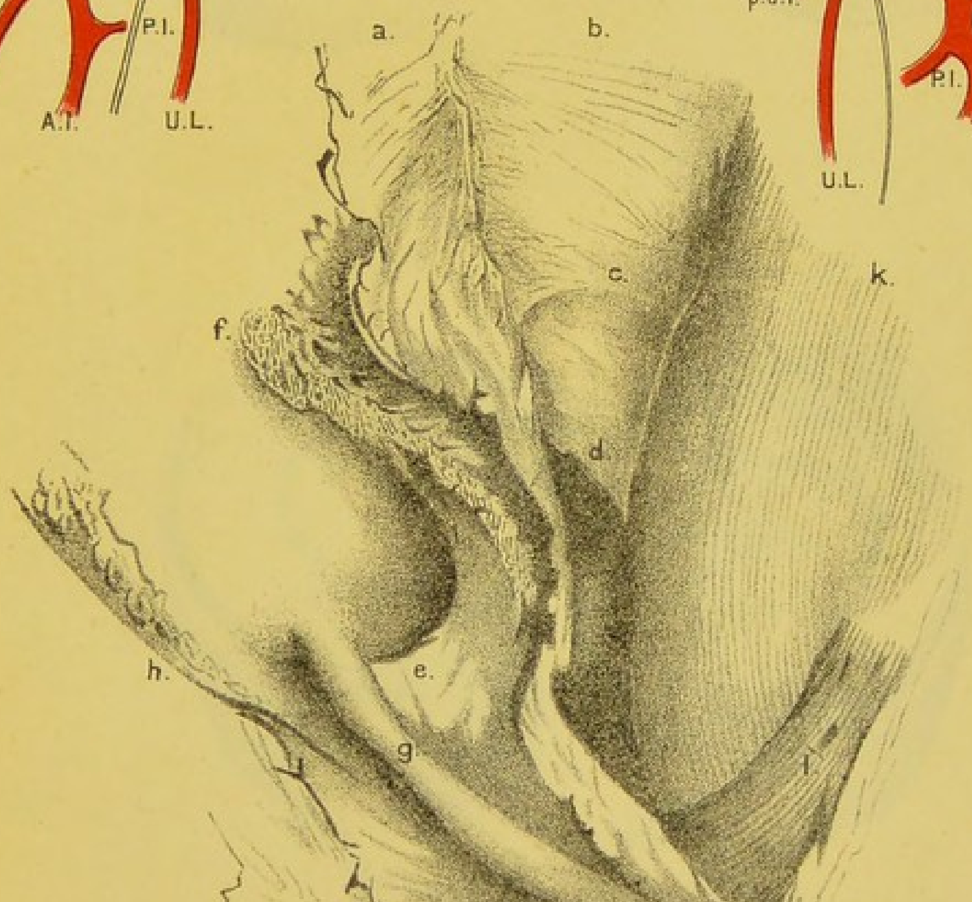

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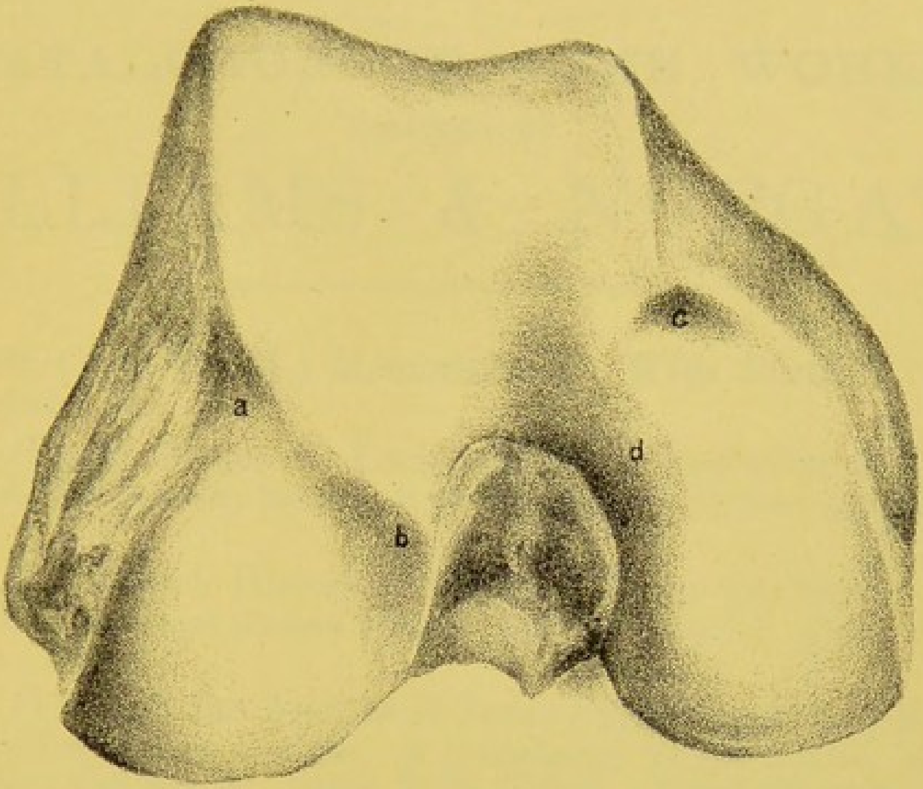
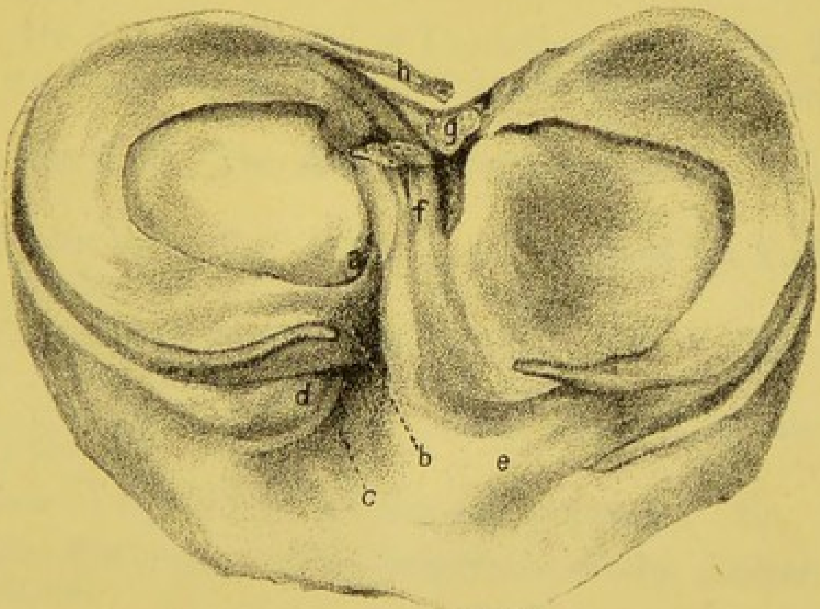


Fig. 2



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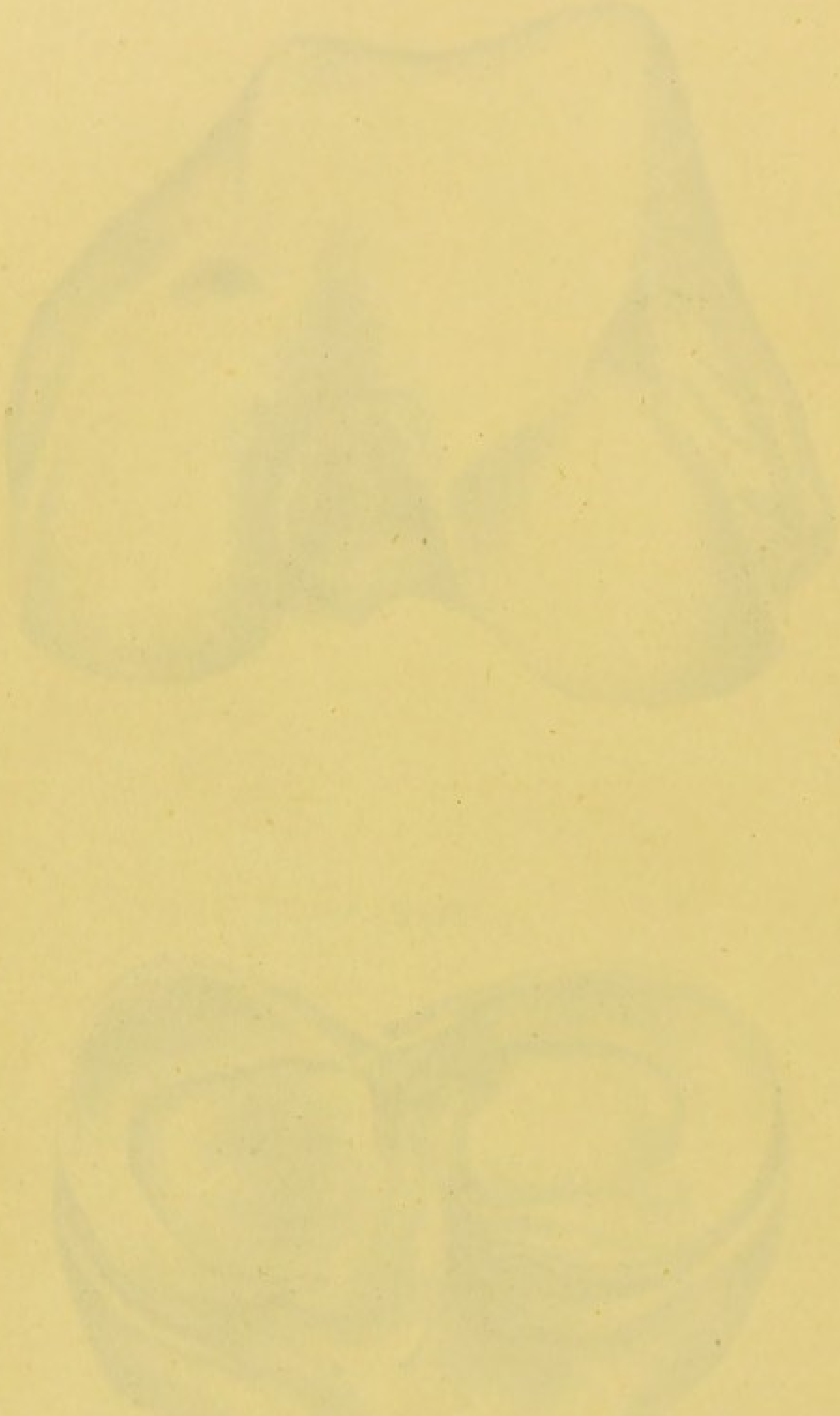

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