MINISTERIE VAN ONDERWIJS, KUNSTEN EN WETENSCHAPPEN
ZOOLOGISCHE MEDEDELINGEN
UITGEGEVEN DOOR HET
RIJKSMUSEUM VAN NATUURLIJKE HISTORIE TE LEIDEN
DEEL XXXI, No. 10 30 Juli 1951

ON THE SINUS LUMBOSACRALIS, SPINA BIFIDA OCCULTA, AND STATUS DYSRAPHICUS IN BIRDS

by

H. C. JELGERSMA, M. D.

The sinus rhomboidalis sacralis or sinus lumbosacralis as it is named by Ariens Kappers (1920) is an interesting anatomical part of the lumbosacral region of the avian spinal medulla. It is found in birds only and neither in reptiles nor in mammals.

Fig. 1 shows the lumbosacral part of the spinal medulla of *Phoenicopterus* seen from the dorsal surface and Fig. 2 represents a diagrammatic transverse section through the lumbosacral part. These figures show some peculiarities that are found in birds only. All vertebrates with hind limbs have a lumbosacral enlargement of the spinal medulla, but in birds this enlargement has become more pronounced through the presence of the lumbosacral sinus. At the dorsal surface of the medulla there is an elongated cleft, which we may call the sinus, and this cleft penetrates rather deep, deeper than the central canal. The cleft is filled up by a plug of peculiar gelatinous tissue,

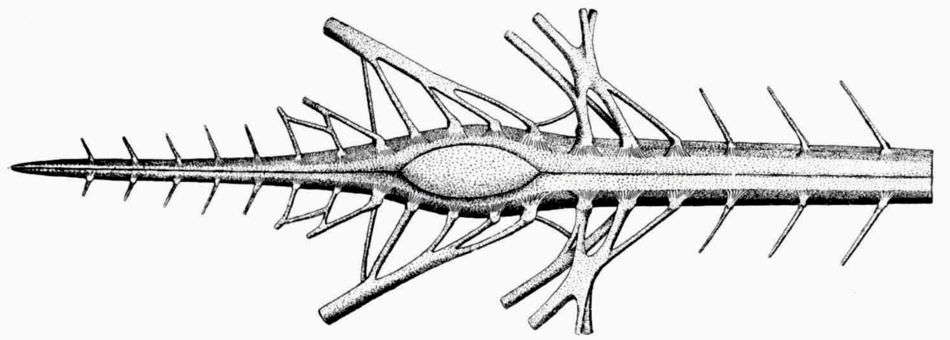


Fig. 1. Spinal medulla of *Phoenicopterus*, dorsal view, with sinus lumbosacralis and corpus gelatinosum. From Imhof (1905).

which protrudes in a marked degree above the surface of the medulla. This tissue is named by Terni (1924) the corpus glycogenicus because the cells contain a great mass of glycogen. Perhaps it is better to use the name corpus gelatinosum, as this name pretends nothing, and glycogen is of common occurrence in tumors and in many other tissues. Ariens Kappers (1924) has shown that this tissue is of a very complicated origin, it is partly glious, partly pial and partly arachnoidal, it contains blood vessels and it is composed of large vacuolized cells. It is remarkable that this gelatinous tissue, when transferred to 70 % alcohol collapses in a few minutes. Imhof (1905) has studied the embryonic development of the lumbosacral sinus and of the gelatinous tissue in *Gallus domesticus* L., and has come to remarkable conclusions. Already on the 9th day of incubation the organ can be seen, and then it occupies the whole median region of the medulla from the ventral to the dorsal surface. In the course of development it retreats to the dorsal part but it continues to envelop the central canal.

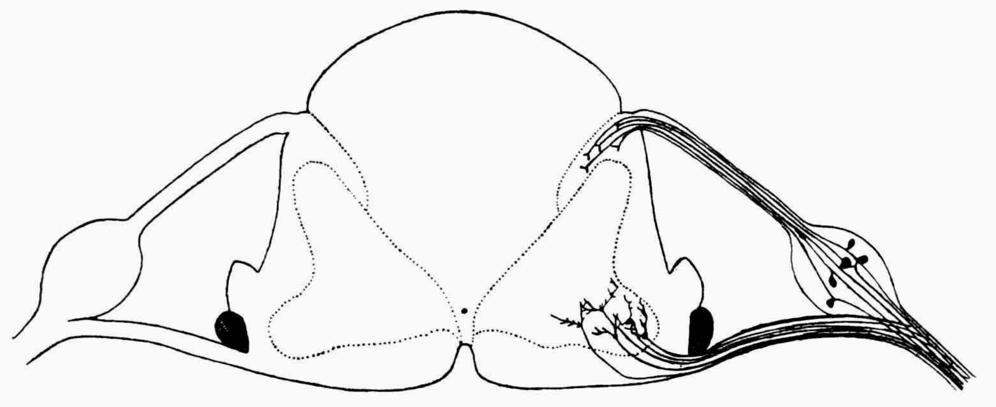


Fig. 2. Cross section of lumbosacral sinus, showing protuberance of corpus gelatinosum; fore and hind roots projected in one plane. From Imhof (1905).

The occurrence of the cleft and this gelatinous tissue of rather obscure origin may remind the neurologist of the so-called myelodysplasia, a pathological feature in human neurology. Myelodysplasia is an anomaly of the spinal cord complicated by clefts and sometimes by a development of tumor tissue; it has been studied by Fuchs (1910), Henneberg (1923), and others. The origin and nature of the myelodysplasia is not clear, but it often manifests itself in the lumbosacral part of the spinal cord, and it is often accompanied by a so-called spina bifida occulta. This is a gap or cleft in the vertebral arch, which in some cases can be seen on a radiogram, and mostly occurs in the last lumbar or first sacral vertebrae. In some cases the vertebral arch is abnormally narrow. The embryonic development of the vertebral arch takes place in two halves, a right and a left half, which later unite in the median line, and it is supposed that a retardation or deficiency in this development gives rise to the spina bifida occulta. But whatever the origin of this spina bifida occulta may be, it is often accompanied by a myelodysplasia and other anomalies of the meninges.

The first question I want to answer is whether birds have an anomaly in the vertebral column or in the sacrum, which has a similarity to the human spina bifida occulta.

But there are more questions to be answered. In Man the spina bifida occulta is often accompanied by a number of other anomalies, which together form the so-called status dysraphicus, an innate constitutional anomaly, which can be found in a rudimentary form in healthy people and may lead to certain neurological diseases among which the most important is the syringomyelia. It has been studied by Bremer (1926 and 1927), Curtius (1933), Bielschowsky (1919), Sillevis Smitt (1935), and others, and this is not the place to describe this status dysraphicus in extenso, but the clinical facts have shown us that doubtless there is a connexion between the following anatomical and functional peculiarities: clefts and myelodysplasia in the spinal cord, a spina bifida occulta, dental anomalies, an abnormal sacralisation, irregularities in the number of vertebrae and ribs, clefts in the palate and an abnormally high placed palate (ogival arch), abnormalities in the function of the urinary bladder, an abnormal sternum, a great length of the arms, deformations of hands and feet, abnormalities in the sensibility, and irregularities in size, situation and number of mammae. As stated above, among neurologists there is no doubt that these anatomical and functional features have a common basis. Therefore the second question is whether in avian anatomy and physiology there are pecularities which have a similarity to the human status dysraphicus.

It may be stated at once that birds have, as normal peculiarities, a more or less well developed spina bifida occulta, and birds have a more or less marked status dysraphicus. I have examined these peculiarities in some detail with the following results.

The sinus lumbosacralis with the corpus gelatinosum are situated in the vertebral canal of the sacrum, therefore we must investigate the sacrum for a possible spina bifida occulta. As for this reason I wanted to examine the dorsal wall of the vertebral canal from the ventral surface of the pelvis, I started my investigations with a pelvis of *Phasianus colchicus* L., from which I removed the ventral wall of the vertebral canal with a strong surgical forceps and in this way exposed the spinal cord. After cutting the nervous roots and lifting up the spinal cord, the sinus with the corpus gelatinosum appeared as a marked protuberance; this tumefaction is lodged in a rather deep excavation in the dorsal wall of the vertebral canal. In the pelves of all other species of birds examined by me I found the same: with the corpus gelatinosum corresponds an excavation in the dorsal wall, which properly might be indicated as the "excavatio sacralis".

When we take away the spinal cord and the meninges, we have a good view of the dorsal wall of the vertebral canal from the inner surface, and then it appears that this dorsal wall may be divided roughly into three parts (Pl. X fig. 1). In the most oral part the surface of the wall is flat and even, in the second part, which has its strongest development in the excavatio sacralis, the surface is interrupted by transverse grooves, and in the third and most caudal part the surface is flat again. The transverse grooves of the second part are caused by the partial separation of the vertebral arches, which in the first and second parts are grown together to a more or less even mass. In most avian pelves it is also obvious that the individual vertebral units in the second part are narrower than those in the other parts. In all the birds examined by me I could observe this second transversely grooved part, in which the vertebral arches are partially separated from each other. This second part extends much farther orally and caudally than the excavatio itself.

Another way of investigation of the excavatio sacralis is by means of median sections of the pelvic region. In the pelvis of *Tadorna tadorna* (L.) (Pl. XI fig. 1) the ventral wall of the vertebral canal in the second part (see above) is rather thin and in the most caudal part it is slightly thicker again. The thinnest is the ventral wall just opposite the excavatio sacralis. When we examine the dorsal wall it is evident that at the excavatio sacralis this wall is very thin. The excavatio is formed only by the thinning of the dorsal wall and not by a protuberance on the dorsal surface, at least in most birds. In the first, the oral part, we see the processus spinosi, grown together to a thin plate; in the second and third parts the processus spinosi have disappeared. This can be observed in many other birds too. Moreover we see in all birds the following peculiarity. In the most oral part the foramina intervertebralia for the spinal roots are single foramina. In the second part these foramina are doubled and in the caudal part they come closer to each other and become single again.

When examining median sections of the pelves of birds of different orders systematic differences are found. In birds of various orders we find a similar thin dorsal wall of the excavatio, for instance in *Vanellus vanellus* (L.) (Pl. XII fig. 1), *Rissa tridactyla* (L.) (Pl. XII fig. 2), *Numenius arquata* (L.) (Pl. XI fig. 2), *Haematopus ostralegus* L. (Pl. XII fig. 3), ,and *Anas crecca* L. (Pl. XII fig. 4). But it seems to me that this dorsal wall in *Alca torda* L. (Pl. XII fig. 5), *Uria aalge* (Pont.) (Pl. XII fig. 6), *Coloeus monedula* L. (Pl. XI fig. 3) and *Melanitta nigra* (L.) (Pl. XI fig. 4) is a little thicker. This is undoubtedly the case with the dorsal wall of the excavatio sacralis of *Accipiter nisus* (L.) (Pl. XI fig. 5). *Phalacrocorax carbo* (Pl. XII fig. 7) has a much thicker dorsal wall, and in *Colymbus arcticus* L. (Pl. XI fig. 6) the dorsal wall is as thick as the excavatio itself is deep. In *Colymbus* we see the thin plate of the processus spinosi also in the third part, and even in the second part. We find the thickest dorsal wall of the excavatio in the Ratitae. This is distinctly shown in a median section of the pelvis of *Casuarius* (Pl. XIII). Here we see the three above named parts of the vertebral canal very distinctly, and also the doubling of the foramina intervertebralia in the second part. It is also obvious that the vertebral units in the second part are much shorter than in the oral and the caudal parts of the pelvis. In the photograph of Pl. XIII we also see the separate processus spinosi of the vertebral arches over the whole length of the sacrum, which in birds of other orders we do not see separately.

We may also investigate these systematic differences in another way; then we must compare the pelves of birds of different orders with the vertebral canal opened from the ventral surface. We may begin with the pelvis of *Fringilla montifringilla* L. (Pl. X fig. 2). Here the whole dorsal wall of the excavatio sacralis is so thin that it is quite transparent for daylight or artificial light, and we see that in the region of the excavatio the vertebral arches are absent: they have not developed. Caudally some more sacral arches have not closed in the median line. That the excavatio sacralis is not quite open on the dorsal surface is due to the fact that in birds behind the vertebral arches there is a bony plate, which is formed by the processus transversi, and in my opinion perhaps also by the ossification of tendons and fasciae. This thin bony plate never disappears, and in *Fringilla* this plate alone forms the dorsal wall of the excavatio sacralis without the vertebral arches taking part.

When examining the pelvis of *Sturnus vulgaris* L. (Pl. X fig. 3) with opened vertebral canal in transmitted light, we see that three vertebral arches in the region of the excavatio, and caudally of these some more sacral arches have not closed in the median line. The gap is closed by the thin bony plate described above. This is like a radiogram of a human spina bifida occulta. About the same defect in the median line we find in *Alauda arvensis* L. (Pl. X fig. 4), *Turdus pilaris* L. (Pl. X fig. 5), *Turdus merula*

L. (Pl. X fig. 6), and *Capella gallinago* (L.) (Pl. X fig. 7). In *Charadrius apricarius* L. (Pl. XI fig. 7), *Fulica atra* L. (Pl. XI fig. 8), *Vanellus vanellus* (L.) (Pl. X fig. 8), and *Lymnocryptus minimus* (Brünn.) (Pl. XI fig. 9) the gap is narrower, and is formed by one or two vertebral arches only. In many other birds the dorsal wall of the excavatio sacralis is no longer transparent, so that we have to examine it in incident light, preferably with a magnifying glass. Thus we see in *Goura cristata* (Pallas) (Pl. X fig. 9) that in the dorsal wall of the region of the excavatio some vertebral arches are narrower in the median part, and that three of these have a distinct notch, indications of an imperfect fusion of the dorsal ends of these arches. The same feature we see in *Anser* (pl. X fig. 10). And in Pl. XII fig. 8 we see a photograph of the pelvis of *Casuarius* with open vertebral canal, opened from the ventral surface. The dorsal wall distinctly shows the three regions described above, and in the second region we see the separated vertebral arches. Here there is not a conspicuous narrowing in the median region, as it occurs in *Goura* and in *Anser,* though two vertebral arches show a narrow notch in the median line. Moreover, in the median line of the entire second region there is a lighter stripe, similar to a cicatrice, obviously caused by retardation in the process of closing of the arches. For the purpose of the present paper it is not necessary to give more details. Radiograms of the pelvis of other Ratitae show that the formation of the excavatio sacralis is about the same as in *Casuarius.*

On the dorsal surface of the pelvis generally there is nothing to be seen of the excavatio sacralis. But in some birds with a wide gap in the vertebral arches, for instance the Passeres, we find a slight protuberance on the dorsal surface of the pelvis, which corresponds to the excavatio sacralis. We observe that the birds with the most strongly marked spina bifida occulta are also the smallest birds, and that the larger birds as the Ratitae have the least developed spina bifida occulta. When, however, we investigate the pelvis of closely related birds of strongly different sizes, for instance, *Lymnocryptus minimus* (Brünn.) and *Capella gallinago* (L.), and also *Goura cristata* (Pallas), *Columba palustris* L. and *Columba oenas* L., and many others, we do not find important differences, the birds of large size showing an even more marked spina bifida occulta than the smaller birds, so that in my opinion in this respect the size of the birds is of little importance.

Thus we have found the following facts. All birds show a more or less marked spina bifida occulta. The more primitive birds have only the excavatio sacralis with a separation of the vertebral arches, and a cicatrice-like irregularity in the median line. The higher developed birds have a more strongly marked spina bifida occulta, i. e., the vertebral arches have not closed in the median line. The dorsal wall of the spina bifida occulta is never quite open, because dorsally of the vertebral arches there is a thin bony plate formed by the processus transversi and probably by the ossification of tendons and fasciae. In more primitive birds the dorsal wall is much thicker.

I have accumulated the following facts concerning the second question: are there in avian anatomy peculiarities which resemble the human status dysraphicus?

1) The dorsal tracts in the spinal cord are very thin.
2) A considerable sacralisation of the dorsal and caudal vertebrae, resulting in a sacrum which is composed of a great number of vertebrae.
3) The absence of a symphysis pelvis between the ossa pubica and the ossa ischii, resulting in a complete opening of the pelvic ring.
4) The absence of a penis in the male and a clitoris in the female birds.
5) The absence of a urinary bladder.
6) A cleft palate, causing a large communication between the nasal and the oral cavities.
7) A reduction in the number of the caudal vertebrae, while the last four to six are united into a single bone, the pygostyle.
8) The absence of claws on the fingers.
9) A great length of the arms.

The above named peculiarities are completely characteristic of a higher developed bird, for instance a sparrow or a finch, but it appeared that many of these anatomical features have a systematic significance. Thus more primitive birds have a male organ, a closed palate, etc. We encounter here similar systematic differences as in the spina bifida occulta of birds. I shall briefly discuss these nine points.

Ad 1). Ariens Kappers (1920) and Brouwer (1915) have measured the relative thickness of the dorsal tracts in *Gallus gallus* (L.), and have compared them with these tracts in reptiles and mammals. They come to the conclusion that the sensible tracts of birds are much thinner than those of reptiles and mammals, and they suppose the sensibility of birds to be poorly developed. Ariens Kappers writes that in another way zoologists have come to the same conclusion. Another cause for the thinness of these dorsal tracts may be found in the prompt ending of the fibres of the dorsal tracts in the medulla, as supposed by the same author. He also remarks that it is a well known fact that the coordination between fore and hind limbs of birds is not as good as in reptiles and mammals. This lesser developed sensibility may remind us of the impairment of sensibility in the human status dysraphicus.

Ad 2). In the bird embryo we find two sacral vertebrae, but in the course of development six caudal vertebrae and a considerable number of dorsal vertebrae are added to the sacrum, which in some adult birds is composed of twenty two vertebrae. In *Archaeopteryx* there is a sacrum of four vertebrae (Heilmann, 1926), so that the process of sacralisation in this genus was just developing.

Ad 3). With the exception of snakes, in which the pelvis is either rudimentary or lacking altogether, all reptiles and all mammals have a ring-shaped pelvis, either with a symphysis pubis only or with a symphysis pubis and a symphysis ischii. On the other hand birds as a rule have no symphysis at all, they have a completely open pelvis with very thin ossa pubica, which are directed posteriorly. But there are exceptions. *Struthio* has a large symphysis pubis in front of the cloaca, and *Rhea* an extensive symphysis ischii behind the cloaca. In *Cygnus, Anser,* and *Colymbus* the ossa pubica, which at their base are directed posteriorly, in the distal ends curve anteriorly and medially, without touching each other. In many cases they are connected by a ligament. The distal ends are paddle shaped. *Anas,* the Accipitres and some Owls have the same direction of the ossa pubica without the paddle shaped ends. These birds have a pelvis which shows a transition between a ring-shaped and a fully opened pelvis. *Archaeopteryx* has a symphysis pubis, *Archaeornis* an open pelvis. In examining embryos of birds we find the ossa pubica directed anteriorly as in reptiles. I am inclined to regard this open pelvis as a raphical deficiency, which shows systematic differences.

Ad 4). Embryos of birds have a rudimentary penis, which disappears in the course of development. The Ratitae, the Anseres, the Crypturi, and the Cracidae, however, have a normally developed male organ. In *Ardea, Phoenicopterus, Ciconia,* and *Otis* we find a slightly but distinctly developed penis. All other adult birds have no male organ at all.

Ad 5). No bird has an urinary bladder, although in the embryonic period the allantois forms a rudimentary urinary bladder, which in adult birds has disappeared. Only *Struthio* has an urinary bladder, which has a size of 13 × 7 cm, but it has proved to be a widened bursa Fabricii. It is therefore uncertain whether we may call this formation a real urinary bladder.

Ad 6). Most birds have a cleft in the oral roof save the Ratitae and the Anseres. *Ardea* has a nearly closed oral roof, the choanae are situated more in front of the palate than in the Ratitae and the Anseres. These anatomical facts, concerning the oral roof as it is seen by opening the bird's beak are given by Barge (1937). Huxley (1867), however, has studied the skeletons and the bony palate of birds and has come to the following conclusions. The Ratitae show in the palate a solid bony bridge in the median line and have therefore no cleft palate. Among the Carinatae the dromaeognathous birds are represented by the single genus *Tinamus,* which has a completely struthious palate. In the desmognathous birds the maxillopalatines are united across the median line and for this reason the palate is not cleft or not fully cleft. The Anseres show a particularly broad communication of the maxillopalatines. The Ardeidae, the Ciconiidae and *Phoenicopterus* show a smaller communication. The schizognathous birds have a fully cleft bony palate, except *Crax globicera,* where the maxillopalatines are united in a single point. In the aegithognathous birds the maxillopalatines never come together. When we compare these anatomical facts given by Huxley with the presence of a male organ, we come to the conclusion that there is a remarkable parallelism between the development of the bony palate and the male organ in birds. The Ratitae, *Tinamus* and the Anseres have a well developed penis, *Ardea, Ciconia* and *Phoenicopterus* a much smaller male organ, and of the schizognathous birds only the Cracidae have a penis. No aegithognathous bird has a male organ.

Ad 7). The tails of *Archaeopteryx* and *Archaeornis* resemble a common reptilian tail and are composed of about twenty conformable vertebrae. In bird embryos a similar tail is found, but adult birds show a considerable reduction in the number of caudal vertebrae, while the last four to six have grown together to form the pygostyle. But in the Ratitae and *Tinamus* there are other conditions. There is no pygostyle and the small tail consists of at least nine conformable vertebrae, which become smaller towards the end. Only the adult *Struthio* has an abnormally formed pygostyle.

Ad 8). The fingers of the reptiles and of *Archaeornis* end in claws, and the same is found in bird embryos (Leighton, 1894). The great majority of adult birds have no claws on the fingers, but in some birds we can find such organs when we push aside the wing feathers. Stresemann (1927-1934) records the occurrence of claws in the Ratitae, the Anseres, the Accipitres, *Chionis, Chauna, Opisthocomus, Phoenicopterus* and the Rails, but Heilmann asserts that only the very young *Opisthocomus* has claws, and the adult bird has not. Mayaud (1950) names the same birds except the Rails.

Ad 9). When we compare the reptiles with the birds we see, that in the latter the length of the fore limbs has greatly augmented, viz., the length of the humerus, the radius and the ulna. The length of the hand has not much altered, but the number of the fingers is reduced from five to three. In recent birds we do not find well developed and separate fingers as in reptiles and in *Archaeornis,* but three deformed fingers with the second and third metacarpalia grown together. Only the Ratitae distinguish themselves by a short or a very short wing. The length of the arm of *Struthio australis* Gurney is 10.2 times the length of a dorsal vertebra, of *Casuarius casuarius* (L.) 6 times. and of *Apteryx australis* Shaw 5 times, but *Cygnus cygnus*

(L.) has an arm length of 36 times the length of a dorsal vertebra and all other birds belonging to the Carinatae have also very long arms. So we see that with the development from reptile to bird the length of the arms has greatly increased, but that the Ratitae form an exception.

The facts given above show that there seems to be a certain connexion between a closed or a cleft palate, a well developed male organ, a little developed male organ, and no male organ at all, a closed pelvis, a nearly closed pelvis, and a fully open pelvis, the absence or the presence of a pygostyle, the length of the arm, and the presence or absence of claws. The sacralisation of the reptiles is 2 to 4 vertebrae, in *Archaeopteryx* we find 4, and in recent birds 14 to 22 vertebrae. To ascertain the number of sacral vertebrae in birds is rather difficult, in many birds it is even impossible without dissecting the sacral region, so another investigator may find slightly different numbers. It seems that the highest number of sacral vertebrae is found in the heaviest birds, which may be explained by the theory of "form and function". It is remarkable that birds as *Colymbus* and *Phalacrocorax* have not the same place as they have in the system of birds, and as we have found in the investigation of the excavatio sacralis. Without doubt the excavatio sacralis of these birds is intermediate between those of higher developed birds and those of the Ratitae; *Colymbus* shows a great resemblance to *Hesperornis* (Heilmann, 1926), and yet it has no male organ, it is schizognathous with a fully cleft palate, it has ossa pubica like *Anser,* and it has no claws. *Phalacrocorax* is desmognathous and the ossa pubica are the same as in *Anas,* but for the rest it has no male organ and no claws. I cannot explain this discrepancy.

The avian anatomical features discussed above have a great resemblance with the human status dysraphicus and we must ask ourselves whether this is a pure superficial resemblance or an essential resemblance. This question cannot be answered with complete certainty, but I am of the opinion that this resemblance is essential and not superficial, because there are so many points of conformity between the human status dysraphicus and the above mentioned anatomical features of birds, of which the most important feature is the spina bifida occulta.

Conclusion.

The anatomy of birds is characterized by a number of features, which we find also in men with a certain constitutional anomaly, the human status dysraphicus. As the most remarkable feature, I found in all birds a more or less developed spina bifida occulta in the sacral vertebral canal, on the level of the sinus lumbosacralis. This spina bifida occulta appears to have systematic significance, and it must be borne in mind that in human neurology the spina bifida occulta is the most important feature of the status dysraphicus. The writer is of the opinion that there is a common base for these avian peculiarities and the human status dysraphicus and that this resemblance is not superficial.

These dysraphical peculiarities in birds are united together and this cannot be explained by the theory of "form and function", but must have its cause in an inner growing tendency.

For the neurologist it may be of interest that the status dysraphicus is not limited to some individuals of the human species, but can be found also in all birds. In this way the status dysraphicus comes to stand on a broader basis. The wide symphysis and the slightly developed penis as a possible symptom of the status dysraphicus may be of interest for human pathology. I am also of the opinion, that the status dysraphicus is not limited to some individuals of the human species and the birds, but that the syndrome in rudimentary form is already an inner tendency in many more vertebrates and especially in primates.

LITERATURE

Ariens Kappers, 1920. Vergleichende Anatomie des Nervensystems. Haarlem.

——, 1924. The lumbosacral sinus in the spinal cord of Birds and its histological Constituents. Psych. en Neurol. Bladen.

Ariens Kappers, Huber, and Crosby, 1936. The comparative Anatomy of the nervous System of Vertebrates, including Man. New York.

Barge, 1937. In: Handbuch der vergleich. Anatomie der Wirbeltiere, vol. 3.

Bielschowsky, 1919. Entwurf eines Systems der Heredodegenerationen des Z. N. S. Journ. f. Psych. und Neurol., vol. 24.

Bremer, 1926. Klinische Untersuchungen zur Aetiologie der Syringomyelie. Deut. Zeitschr. f. Nervenh., vol. 95.

——, 1927. Die pathol. anat. Begründung des Status dysraphicus. Deut. Zeitschr. f. Nervenh., vol. 99.

Brouwer, 1915. Die biologische Bedeutung der Dermatomerie. Folia Neurobiologica, vol. 9.

Curtius, 1933. Über Degenerationszeichen. Eugenetik.

Fuchs, 1910. Über Bezeichnungen der Enuresis noct. zu Rudimentärformen der Spina bif. occ. Wien. Med. Wochenschr.

Henneberg, and Koch, 1923. Zur Pathogenese der Syringomyelie. Monatschr. f. Neur. und Psych., vol. 54.

Huxley, 1867. On the Classification of Birds. Proc. Zool. Soc.

Heilmann, 1926. The Origin of Birds. London.

Imhof, 1905. Anatomie und Entw. des Lumbalmarkes der Vögel. Arch. f. mikr. Anat. u. Entw., vol. 65.

Leighton, 1894. The Development of the Wing of Sterna wilsonii. Amer. Naturalist.

Mayaud, 1950. In: Traité de Zoologie (Grassé), vol. 15 (Oiseaux). Paris.

Terni, 1924. Richerche sulla cosidetta sostanza gelatinosa, etc. Arch. Ital. di Anat. e di Embr., vol. 21.

Sillevis Smitt, 1935. Over de Vormenrijkdom van heterodegeneratieve Verschijnselen. Diss., Utrecht.

Stresemann, 1927-1934 Sauropsida: Aves. Handb. d. Zool. (Kuekenthal-Krumbach), vol. 7, 2.

EXPLANATION OF THE PLATES

Plate X

Sacral region of the vertebral column of various birds, ventral view, ventral wall of vertebral canal removed. Anterior region in the upper parts of the figures. Figs. 1, 9, and 10, in incident light; figs. 2-8, in transmitted light, showing the transparency of parts of the dorsal wall.

Fig. 1, *Phasianus colchicus* L., × 2¼; fig. 2, *Fringilla montifringilla* L., × 5½; fig. 3, *Sturnus vulgaris* L., × 5; fig. 4, *Alauda arvensis* L., × 5; fig. 5, *Turdus pilaris* L., × 5; fig. 6, *Turdus merula* L., × 5; fig. 7, *Capella gallinago* (L.), × 5; fig. 8, *Vanellus vanellus* (L.), × 4½; fig. 9, *Goura cristata* (Pallas), × 1⅔; fig. 10, *Anser* spec., × 1⅔.

Plate XI

Sacral region of the vertebral column of various birds. Figs. 1, 2, 5, and 6, median sections, anterior end to the left; figs. 3 and 4, median sections, anterior end to the right. Figs. 7-9, ventral view, ventral wall of vertebral canal removed, anterior region in the upper parts, in transmitted light, showing the transparency of parts of the dorsal wall.

Fig. 1, *Tadorna tadorna* (L.), × 4; fig. 2, *Numenius arquata* (L.), × 4; fig. 3, *Coloeus monedula* (L.), × 5; fig. 4, *Melanitta nigra* (L.), × 3; fig. 5, *Accipiter nisus* (L.), × 4; fig. 6, *Colymbus arcticus* L., × 3; fig. 7, *Charadrius apricarius* L., × 4; fig. 8, *Fulica atra* L., × 3; fig. 9, *Lymnocryptes minimus* (Brünn.), × 5.

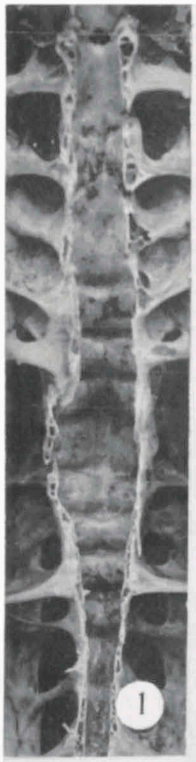
Plate XII

Sacral region of the vertebral column of various birds. Figs. 1, 3-6, median sections, anterior end to the left; figs. 2 and 7, median sections, anterior end to the right. Fig. 8, ventral view, ventral wall of vertebral canal removed, anterior end in the upper part, in incident light.

Fig. 1, *Vanellus vanellus* (L.), × 6; fig. 2, *Rissa tridactyla* (L.), × 5; fig. 3, *Haematopus ostralegus* L., × 4; fig. 4, *Anas crecca* L., × 6; fig. 5, *Alca torda* L., × 3; fig. 6, *Uria aalge* (Pont.), × 4; fig. 7, *Phalacrocorax carbo* (L.), × 2; fig. 8, *Casuarius* spec., × 1⅕.

Plate XIII

Casuarius spec., median section of the sacral region of the vertebral column, anterior end to the left. × 1⅕.

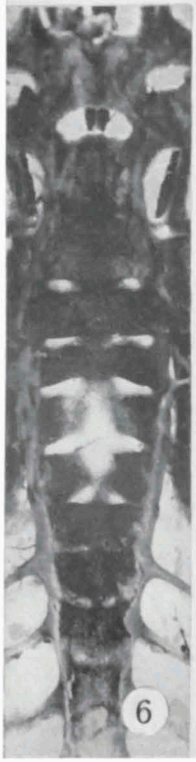

1


2


3


4

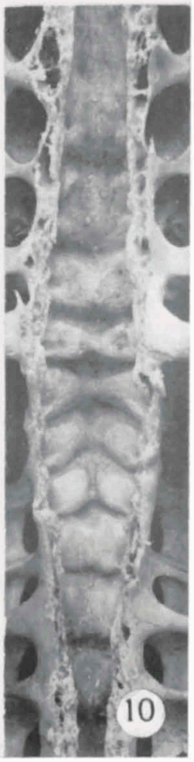

5

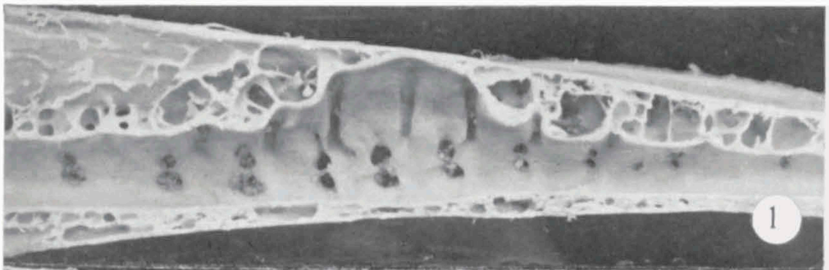

6

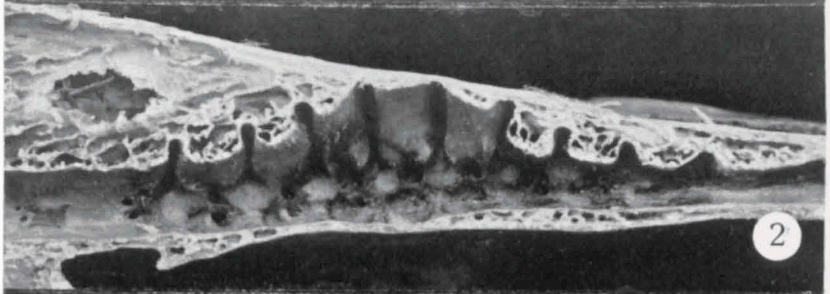

7


8

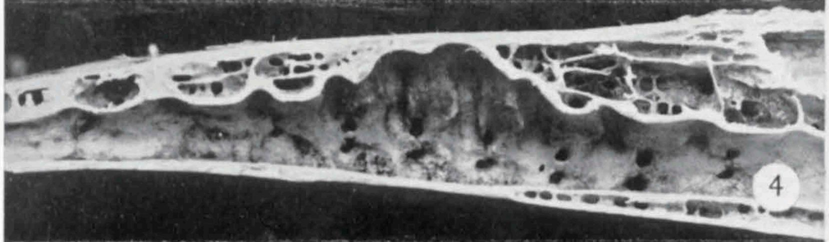

9

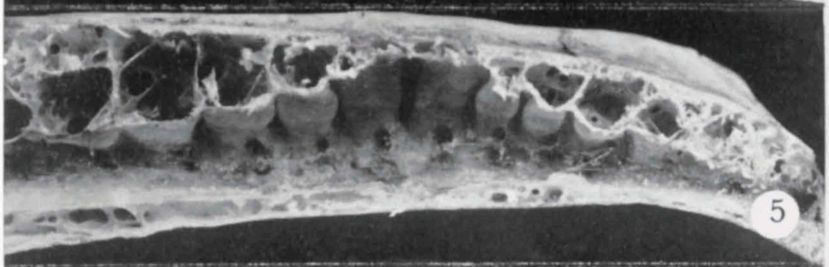

10

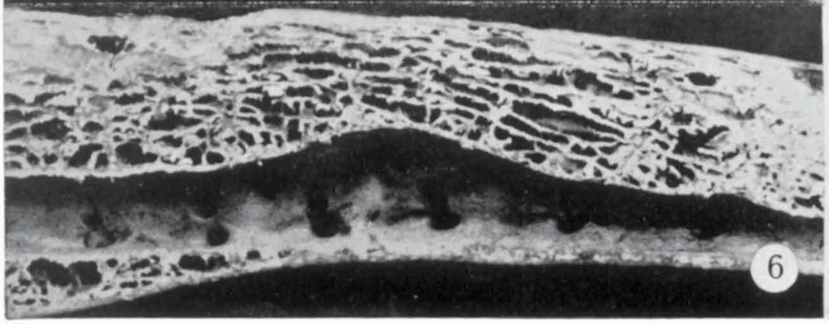

1


2

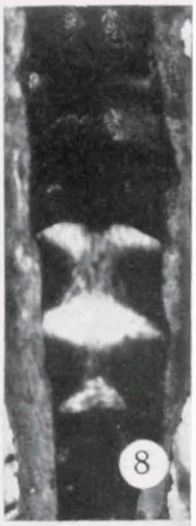

3

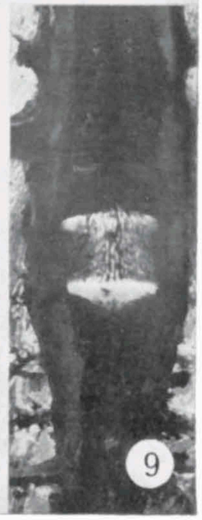

4

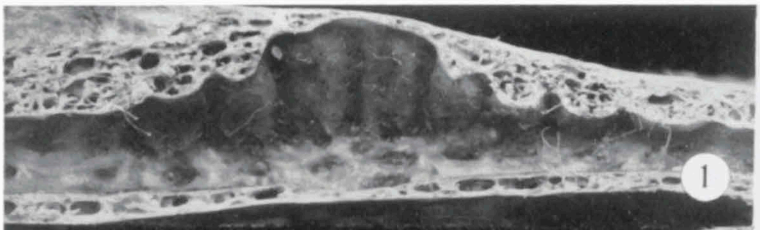

5

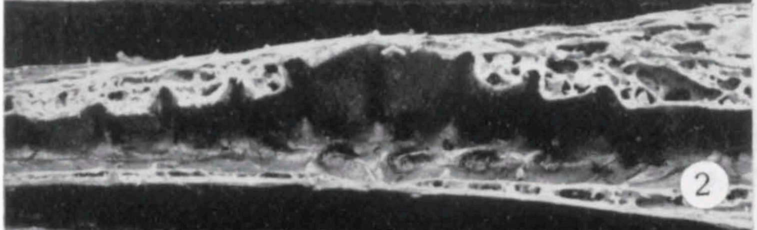

6


7


8

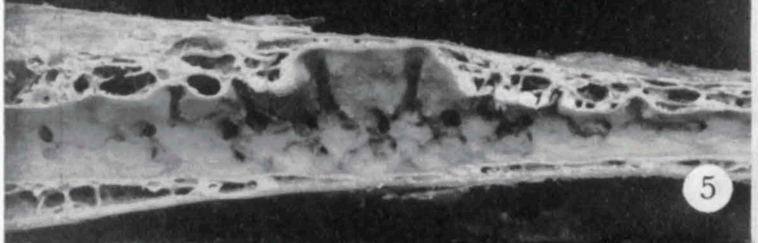

9

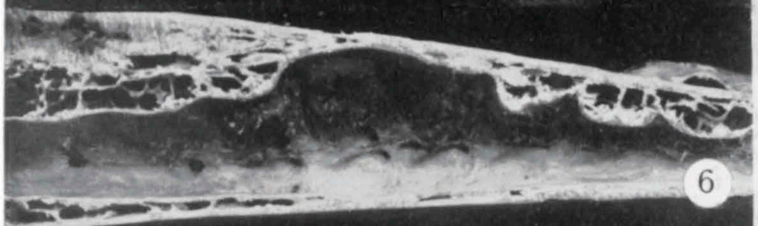

1

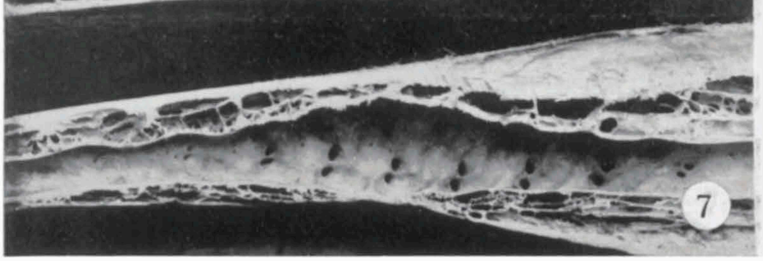

2

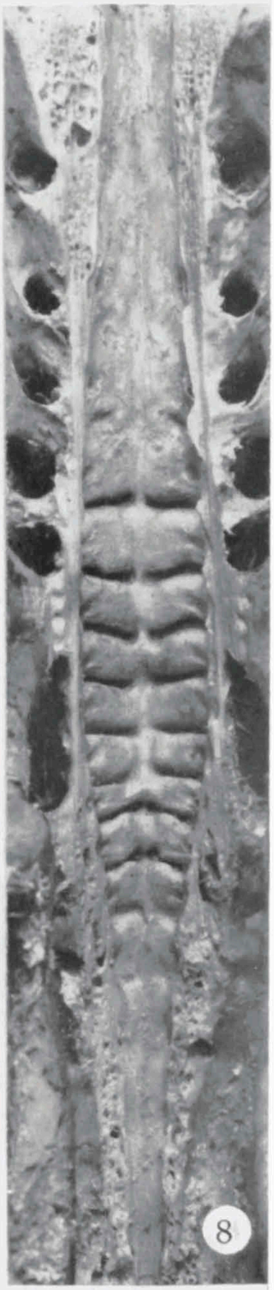

3


4


5


6


7


8