Anatomy. — "*On the development of the sternum in reptiles*". By CHR. VAN GELDEREN. (Communicated by Prof. L. BOLK).

(Communicated at the meeting of June 25, 1921).

Comparative anatomy generally indicates as sterna those parts of the skeleton that lie in the ventral median line of the trunk-wall. In the reptiles, which will be discussed in this paper, we have to distinguish between episternum and sternum s. strictiori. The sauria and crocodilia possess a sternum s. str.; with the exception of the rhiptoglossa they have an episternum besides. Considering the uncertainty existing about the development of the above named sterna, for the present only the histological build of the adult reptiles may be named as the only difference between the two. The episternum consists of bone, the sternum s. str. of cartilage, which is often calcified. This communication only concerns itself with the development of the sternum s. str.

We owe to RATHKE the first data about the development of the sternum, in reptiles as well as in birds and mammals [1]). He found in Lacerta agilis, that in early embryonic stages the sternum consisted of two entirely separated parts. Each part was a strand of tissue consisting of a dense mass of cells, which connected the ventral ends of the future vertebro-sternal ribs. Afterwards the two sternal parts fused in cranio-caudal direction. In Anguis fragilis, on the contrary RATHKE found that the sternum developed apart from the ribs. Later [2]) on RATHKE published his experiences in embryos of crocodiles. They were entirely in accordance with those in Lacerta. One cannot conclude from RATHKE's works whether he saw any fundamental difference between the two ways of development of the sternum described above, separated from the ribs in anguis connected with the ribs in lacerta and crocodilus; neither can one conclude whether in his opinion there is a genetic relation between the sternum and the ribs in lacerta and crocodilus, in other words, whether the sternum is a product of the ribs inserted into it.

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[1]) H. RATHKE. Ueber den Bau und die Entwickl. des Brustbeines der Saurier Königsberg 1853.

[2]) H. RATHKE. Ueber den Körperbau und d. Entwickl. der Krokodile. Braunschweig 1866.

GÖTTE [1]) examined the development of the sternum in Chemidophorus spec. and in Anguis fragilis. In Chemidophorus the first formation was paired and consisted of a triangular widening of the ventral end of the first (future) vertebro-sternal rib. This primitive formation developed caudally only so far as further ribs attached themselves to it, so not independently. Moreover GÖTTE thinks it probable that the last cervical rib, which in the further development is more and more removed from the sternum, has also taken part in the first formation of the sternum. In Anguis the sternum was formed out of the widened end of the first rib, which soon after this was loosened from the sternum.

Apparently the embryos examined by RATHKE were too old for the purpose. The results of WIEDERSHEIM's [2]) examinations of Lacerta and Anguis agree very well with GÖTTE's experiences. Only he thinks it probable that also the last but one cervical rib takes part in the formation of the sternum. Also in crocodilus biporcatus the sternum, according to WIEDERSHEIM, is formed by the ribs.

SCHAUINSLAND [3]) describes the sternal formation in Sphenodon, first connected only with one rib, afterwards with three. Out of these one has to think the sternum has been formed. And, lastly, according to BOGOLJUBSKI [4]) the paired first sternal formation in Lacerta and Anguis is formed without any original connection with ribs, is therefore an autochthonie formation. In short, according to the generally prevailing opinion the sternum of the reptiles is formed out of the ribs [5]). Only BOGOLJUBSKI supposes the sternal formation in the reptiles to be autochthonic.

It is advisable to mention here that there are some more theories on the development of the sternum of higher amniota, the mammals. According to PATERSON [6]) the first formation of the sternum consists of an unpaired, dense mass of mesoblastcells, lying in the median line. Later on one finds two sternal bands because the median part has become poorer in cells. The relation between ribs and sternum is secondary, on the other hand there is a primary connection between the median formation and the shoulder girdle. WHITEHEAD and WADDEL [7]) suppose the mammaliam sternun to be built out of

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[1]) A. GÖTTE. Archiv. f. mikrosk. Anat. Bd. XIV, 1877.

[2]) R. WIEDERSHEIM. Das Gliedmaszenskelett der Wirbelthiere. Jena, 1892.

[3]) H. SCHAUINSLAND. Archiv. f. mikrosk. Anat. u. Entw.gesch. Bd. LVI, 1900.

[4]) S. BOGOLJUBSKI. Zeitschr. f. Wissensch. Zool. Bd. 110, 1914.

[5]) O. HERTWIG's Handb. d. vergl. u. experim. Entwickl.lehre. Jena.

[6]) A. M. PATERSON. Journ. of Anat. and Physiol. Vol. 35. 1900.

[7]) R. H. WHITEHEAD and WADDEL. Americ. Journ. of Anatomy. Vol. 12, 1911.

two autochthonic sternal bands, and moreover out of a third, also autochthonic, median formation. This median formation is independent of the sternal bands, and also of the shoulder girdle. This appears most clearly by the fact that the median formation is present also there where the clavicula is absent, so where the shoulder girdle does not reach the sternum. HANSON [1]) sees in the median formation part of a large blastema with the shape of a horse-shoe, out of which the two shoulder girdles and the cranial part of the sternum are formed.

All biologists who examined the development of the reptilian sternum agree that the sternal bands are fused after their becoming cartilaginous. And after that, calcification may follow.

In order to get an opinion founded on personal observation I examined a number of sauria-embryos. My experiences may follow here.

For this examination I had at my disposal a dozen embryos of Gongylus ocellatus, sectioned into series, and two of Ptychozoon homalocephalum. Besides, transversal series were made of some

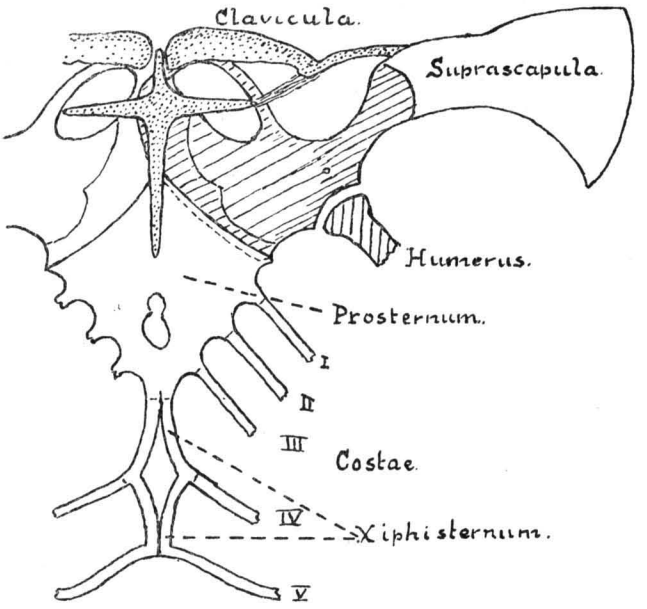

Fig. 1. Sternum and shoulder girdle of Lacerta agilis.

sixteen embryos of Lacerta agilis. All series had been sectioned 10 μ thick, most of them had been coloured with haematin. The development of the sternum could be very well observed in this series of

[1]) F. B. HANSON. Americ. Journ. of Anatomy. Vol. 26, 1919.

embryos of lacerta, which was sufficient in all respects. Therefore I shall begin with a description of my experiences with lacerta.

For further elucidation the shoulder girdle and sternum of an adult lacerta agilis have been drawn from nature in diagram 1. The whole complex has been drawn in a plane. One may observe that at both sides of the prosternum three ribs are inserted by syndesmoses, and that the xiphisternum supports two ribs. It would be better to speak of two xiphisterna here, as at the level of the fifth rib there is only a syndesmotic connection in the median plane. Prosternum and xiphisternum are also connected by syndesmoses Coracoideum (hatched) and sternum are connected by a diarthrosis; the coracoideum fits in a groove, sulcus articularis coracoideus, of the sternum. Clavicula and episternum, which are further left out of consideration, are dotted.

In the prosternum we find a fontanel closed by membrane.

The youngest embryo at my disposal, Lacerta ag. D. (N.T. [1]) about 22) had not yet any sternal formation. Neither was there anything to be found of the shoulder girdle as yet. Only in the extremity a thickening of the mesenchym, the first formation of the humerus, was found.

The next embryo, Lacerta ag. S. (N.T. about 24) differs from the preceding one in so far that the formation of the shoulder girdle, continuous with that of the humerus, is visible. As this shoulder girdle is as yet very vaguely outlined, one can hardly distinguish any shape in it, at most a ventral coracoidal part and a dorsal scapular part. Now if one looks more in a caudal direction, one finds in the sidelong wall of the trunk a densening of the mesenchym, which is unconnected with any other skeleton-formation. This is the first formation of the sternum, which as yet consists exclusively of blasteme, dense mesenchym. In diagram 2 a transversal section has been drawn, in which there is a sternal formation. The section is not quite transversal; in the lower part we see the humerus, in the upper part radius and ulna. Still the left hand as well as the right hand sternal formation are present in the section. This proves that the sternal formation has already been extended in cranio-caudal direction. It is not possible to demonstrate in pictures of transversal sections the independences of the sternal formation of the humeral zone (in casu the coracoideum). As will appear later on the more obliquely sectioned series of Gongylus ocellatus are better suited for this purpose.

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[1]) Normentafel. Lacerta agilis von K. Peter.

The next stage is represented by the embryos Lacerta ag. E and F (N.T. about 26), which show nearly the same stage of development. The outline of the shoulder girdle has become clearer. The coracoidal and the scapular part can very well be recognized. In

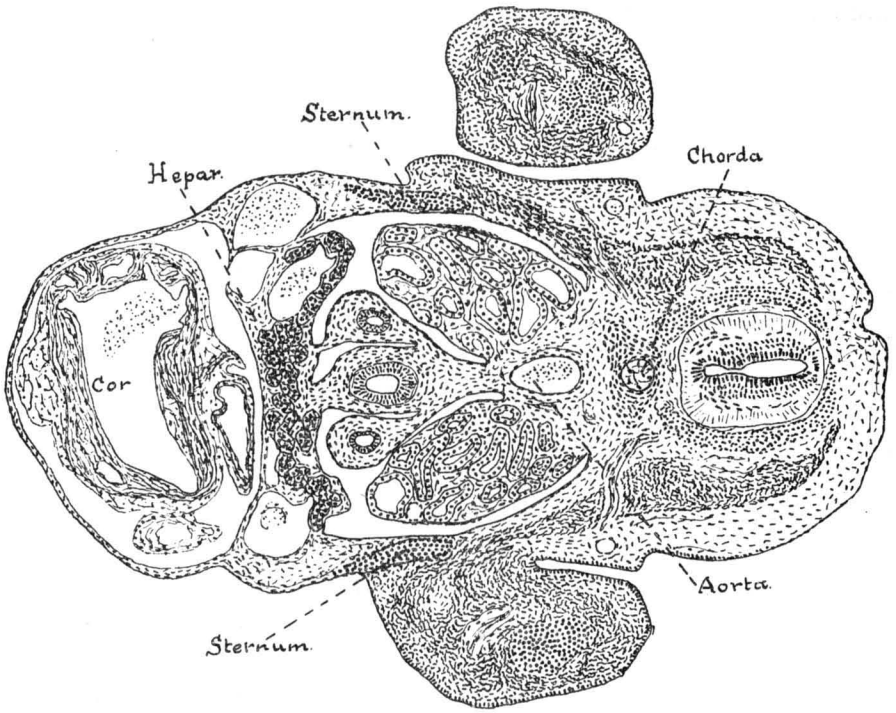

Fig. 2. Lacerta agilis S. transversal.

the humeral diaphysis praechondrium is found. In comparison with embryo D there is a further progress in the increased size of sternum and shoulder girdle. Sternum and shoulder girdle have grown in each other's direction. This has caused the layer of undensened mesenchyme, ab origine found between them, to become less clear.

A considerable progress in development may be stated in the embryo Lacerta ag. I (N.T. about 28). In the humerus we here find for the first time cartilage. In their further growth sternum and coracoideum have come so near to each other that they appear together in transversal sections. It has become almost impossible to outline them clearly with respect to each other. In the accompanying diagram we see an only slightly lighter zone of partition. If the embryos described above had not been examined, the sternum would, on the ground of this embryo, certainly have been declared to be a product of the coracoideum, and this stage would have been interpreted as the first stage of the sternum being cut off its matrix, the coracoideum. The ribs have approached the sternal formation

up to some distance, so that the length of the sternal forman to can now also be indicated with respect to the ribs. In caudal direction the sternum reaches to the level of the third rib. Between the sternal formation and the ventral ends of the ribs we find everywhere loose mesenchyme.

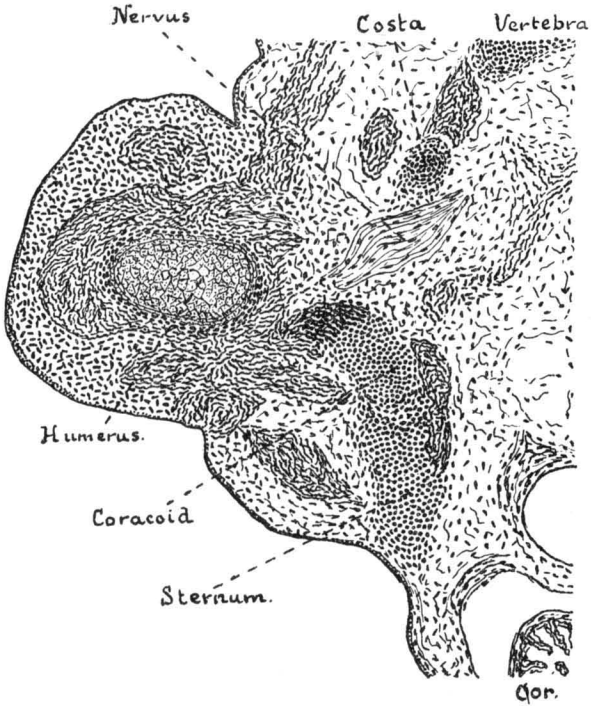

Fig. 3. Lacerta agilis I. transversal.

In the embryo Lacerta agilis K (N.T. about 29), which is only slightly older than the preceding one, again a clear partition of coracoideum and sternum is present, a fact which strikes one also in studying the embryo Lacerta ag. G., which represents the same stage of development as the embryo K. The zone of partition, here again present, is nothing else than the formation of the later sterno-coracoidal articular cavity. Both the embryos G and K have a paired sternal formation, reaching caudally to the level of the third rib, and separated from the ribs by loose mesenchyme.

In the embryo Lac. agilis H (N.T. about 30) a considerable progress is noticed. This progress concerns the form of the parts of the skeleton as well as the histological differentiation. In the vertebral arches we find cartilage, round the cartilaginous humeral diaphysis we find a thin coat of perichondral bone. Diagram 4 brings us one half of a transversal section in which the ventral end of the first thoracic rib (the first future vertebro-sternal rib) is found. The purpose of the

diagram is to demonstrate the relation between the first rib and the sternal formation. In this embryo, which has reached a rather advanced stage of development, as is proved by the advanced histological differentiation, still all connection between sternum and ribs

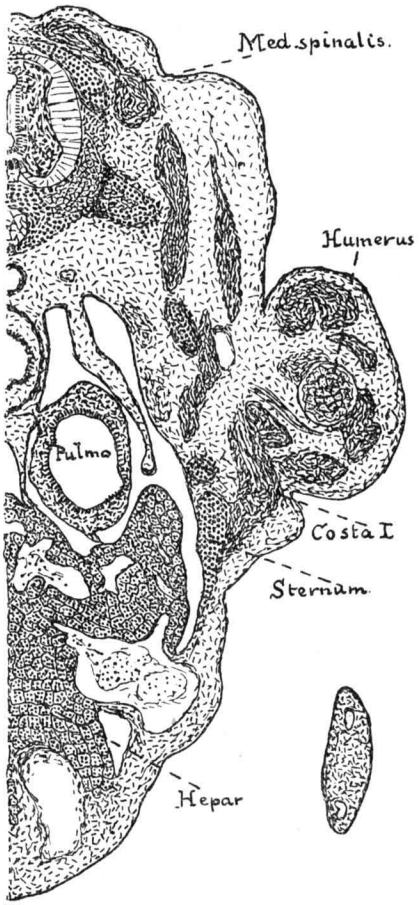

Fig. 4. Lacerta ag. H. transversal.

is wanting. The second and third ribs namely behave exactly in the same way as the first.

The next embryo, Lacerta ag. J. (N.T. about 31) is distinguished from all those described above by the possession of a sternal formation, which extends in a caudal direction past the third rib. The sternal formation here consists of one larger cranial part, in which praechondrium is found and with which three thoracic ribs are connected by moderately dense mesenchym, and a small caudal part, which has the appearance of an offshoot of the former. This offshoot is still purely dense mesenchym and ends at a short distance

of the ventral end of the fourth rib, separated from the latter by loose mesenchym. At the description of the embryo Gongylus ocell. L. one finds entirely similar relations made clear by two frontal sections (diagr. 6).

Embryo Lacerta ag. L. (N.T. about 31) shows little progress as compared with embryo J. The principal point is that the two sternal ridges are here connected with three ribs by entirely densened mesenchym. The relation between the fourth rib and the sternum has not undergone any change. The extension of the praechondrium in the sternal formation has increased. The caudal offshoot is still entirely free from praechondrium. If one compares diagrams 2 and 4, one sees that the sternum in diagr. 4 is still found at the same place as in diagr. 2 viz. in the lateral trunk-wall. Shifting towards the ventral median line has not yet taken place. In the older embryos following, this shifting becomes clearer and clearer. One might suppose some connection to exist between this shifting and the longitudinal growth of the ribs with which the sternal formation is now connected. It seems to me better to take the relative decreasing of the heart-bulge for the only cause of this. For though in Anguis the sternum and the only vertebro-sternal rib are soon definitively separated (WIEDERSHEIM), still the sternal halves shift towards the median line to grow into one whole there.

In embryo Lacerta ag. N. (N. T. about 32) we find a beginning of important phenomena of development. In the first place a densening of mesenchym has appeared here between the end of the fourth rib, and the still blastematical end of the sternum. Here is as yet no question of complete joining, as the intermediate zone has not yet reached the same state of density as the sternal formation. The ventral end of the fifth rib, the last of the future vertebro-sternal ones, is situated thirteen sections caudally (130 μ) to the insertion of the fourth rib to the sternum in the straight ventral muscle.

In the second place I have to mention here that, in spite of its further development in comparison with embryo L, the sternal formation does not reach caudally past the insertion of the fourth rib.

From various circumstances it appears that embryo Lacerta ag. N. (N. T. ab. 33) is further developed than the preceding are. As regards the sternal formation, here too the fourth rib is connected with the blastematic caudal end of the sternum by completely densended mesenchym. The end of the fifth rib is situated only eight sections (80 μ) caudally to the insertion of the fourth rib to the sternal band. Consequently the fifth rib has been lengthened, and has grown in the direction of the sternal formation. But, conversely,

the sternal formation has not been lengthened past the fourth rib in the direction of the fifth. I think I have to conclude from this that the autochthonic sternal formation does not reach further caudally than up to the insertion of the fourth rib. The two sternal bands in this embryo have come cranially within a very short distance of each other. Neither here nor in any of the younger embryos there could be observed anything like a median formation that was also to grow into one whole with the sternum. Still the sternal ridges are here found immediately before the beginning of the growing together in the median line, as appears from the following embryo.

I found a somewhat older stage in the embryo Lacerta ag. Q. (N. T. about 33). The sternal bands, which here were cartilaginous, had already fused in the most cranial part. Caudally to the later breastbone-fontanel as yet no joining had taken place in the median line. All five ribs were joined by means of cartilage to the sternum, which was also cartilaginous; so they formed together one large continuum of cartilage. Moreover the syndesmoses are wanting, which in the adult lizard separate the xiphisterna from the prosternum.

In the embryo Lacerta ag. Q. (N. T. ab. 33—34) the sternal bands have fused cranially, as in embryo P; then follows the region of the breastbone-fontanel; still more caudally, on a level with the insertion of the third rib, the sternal bands are again situated close to each other. A thin layer of blastema proves that no fusion has as yet taken place here. Caudally to this part the sternal ridges diverge, never to reach each other again (c. f. diagr. 1).

Still completer is the fusion of the sternal bands in embryo Lacerta ag. R (N. T. ab. 34—35), while in embryo Q there was only a blastematic connection in the median line, in embryo R a cartilaginous connection is formed caudally to the fontanel. Moreover the two xiphisterna have joined on the level of the fifth rib. So in this embryo, the oldest examined by me, the adult form has been reached, at least in the main. A difference is still formed by the absence of all syndesmoses. They have to be formed secondarily in places where cartilage existed first. Therefore these syndesmoses have no morphological value; they are not lines of division to which, strictly taken, any importance may be attached. They have only a mechanical importance.

Of Gongylus occellatus I had eleven embryos at my disposal. Older stages, like the embryos P, Q and R of lacerta were wanting. Neither did I possess an adult specimen, nor an image of the adult sternal apparatus. So I can only give a few data established in

literature concerning the structure of the latter In. Gongylus, as in Lacerta, three ribs are fixed to the Prosternum. To the xiphisternum, too three ribs are fixed (HOFFMANN [1]), PARKER [2]), FÜRBRINGER [3]). With the exception of this difference, which had no importance for the study of my material, the relations agree with those of Lacerta.

The embryo Gongylus ocellatus F. and G. agree in their stage of development with the embryo S. of Lacerta. They contain a blastematic sternal formation, which is clearly unconnected with the formation of the coracoideum.

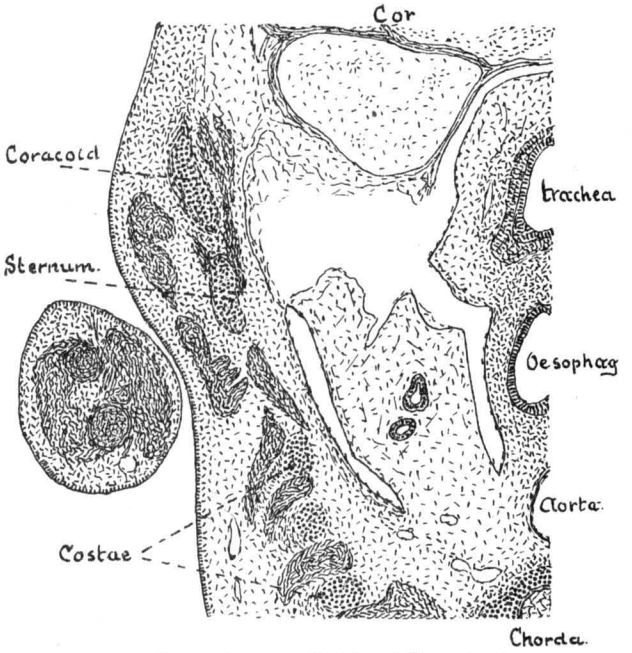

Fig. 5. Gongylus ocell. F. obliquely frontal.

Thanks to the oblique direction of sectioning it was possible to draw the abovesaid relation between sternum and coracoid in diagr. 5, which represents part of such an oblique section. Also by the peculiar direction of sectioning, in this section the sternum is situated dorsally to the coracoideum. Between the two we find a small layer of loose mesenchym. In the diaphysis humeri we find already some praechondrium.

A following stage is represented by the embryos Gong. ocell. A and B. They are similar to the embryos E and F of lacerta. The

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[1]) C. K. HOFFMANN in BRONN's Klassen u. Ordn. des Thierreichs. Reptilien.

[2]) W. K. PARKER. Monogr. on the Struct a. developm. of Should. g. and Stern. Ray Soc. 1868.

[3]) M. FÜRBRINGER. Jenaische Zeitschr. Bd. 34, 1900.

sternal formation is not clearly separated from that of the coracoideum; the cause of this state of things lies in the fact that the two have grown in each other's direction. The humerus is here for the greater part built up of cartilage. The ribs are still separated from the paired sternal formation by loose mesenchym.

Still further developed are Gong. ocell. C and D. They have a breastbone formation that is clearly separated from the coracoideum by a thin dividing layer, the formation of the diarthrose. The stage in which the division of sternum and coracoid was almost impossible, is over here. The three ribs, which end within a short distance of the sternum are still entirely unconnected with A. The sternal formation does not reach further caudally than the third rib.

The embryos E and J of Gong. ocell., too represent one and the same stage. As a basis for description I take embryo E. Sternum and coracoid are definitively separated. Three ribs are connected with the praechondral prosternum by mesenchym that is moderately dense.

A caudal blastematic offshoot of the sternal ridge grows in the direction of the fourth rib, but is still entirely unconnected with it. As some few sections were wanting I could not with certainty fix the relation between all prosternal ribs separately and the sternum. Undoubtedly the above said observations can be generally applied, as is proved by Gong. ocell. I. In this embryo there is one and the same relation between each of the three ribs and the sternum, viz. that of a still less clear connection than in embryo E. The caudal offshoot of the sternal formation, too, is smaller here. On the other hand the relation towards the coracoid is the same.

Embryo Gong. ocell. L. corresponds with embryo lacerta J. On both sides three ribs are joined to the sternal formation by completely dense mesenchym. An offshoot grows in a caudal direction towards the fourth rib, as is shown in diagr. 6. In this diagram two consecutive sections out of this series have been partly drawn. The direction of sectioning was here frontal to the thorax. The sternal formation has here to a large extent shifted in medio-ventral direction

In embryo K, lastly, the one furthest developed, the fourth rib, too, is joined blastematically to the sternum. For want of older embroys the development of the xiphisternum in Gongylus could not be followed any further. From what precedes it appears that the results obtained in Gongylus are a confirmation of the experiences in Lacerta.

Finally, I had an opportunity to study two series of young embryos of Ptychozoon homalocephalum.

In the embryo Ptychoz. hom. A we find a very early stage. A blastematic paired sternal formation, unconnected with any other skeleton-formation, is found in the lateral trunk-wall.

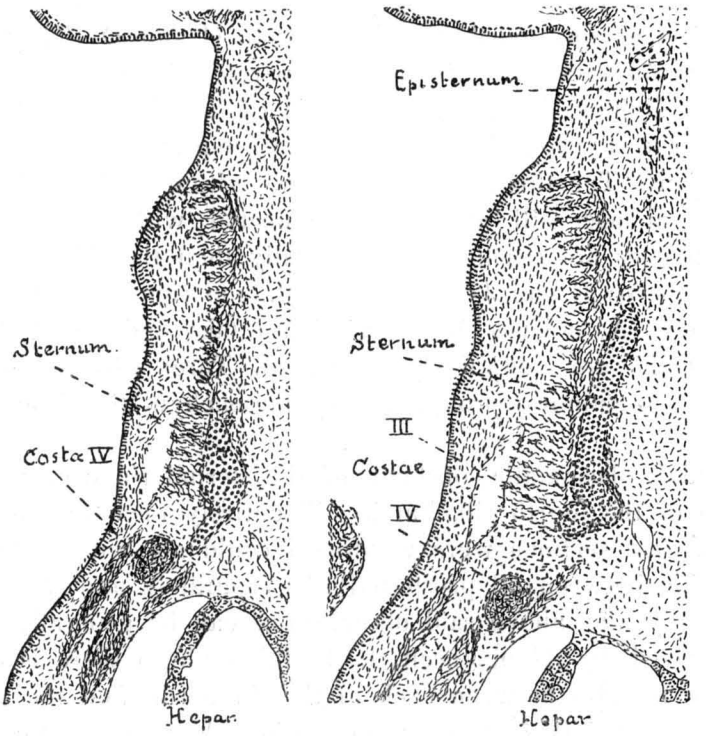

Fig. 6. Gongylus ocell. L. frontal.

If one sees the smallness of the ribs, and that in the humerus no cartilage is as yet present, one may conclude that the maximal approach of sternum and coracoideum has not been reached by a long way, in other words that the zone of division does not represent the formation of the articular cavity. So this embryo corresponds on the whole with embryo S. of lacerta.

The embryo Ptychoz. hom. B is much older. On both sides one finds a sternal formation to which three ribs have been joined.

In the preceding words my experiences in studying some thirty embryos were rendered separately. We shall now consider what conclusions they enable us to draw.

In the first place: the youngest formation of the sternum is paired and autochthonic; in so far I quite agree with Bogoljubski. If one has come to this conclusion, one has to ask oneself this question: What part of the definite thorax-skeleton was formed out of this

autochthonic sternal formation, or in other words: where are the divisions between the autochthonic breastbone and the ribs situated? With regard to the first three vertebro-sternal ribs the answer is easy. Here the abovesaid divisions correspond with the definitive syndesmoses sterno-costales. With regard to the fourth and fifth ribs, in order to get certainty there, one has partly to take for basis magnitudinal relations such as are represented in diagram 7. In diagr. 7*d* the little crosses indicate the situation of the definitive sternocostal syndesmoses. It appears from the diagram that the place where the fourth rib has placed itself against the autochthonic sternal band (7*c*) is not the same as that where later on the syndesmoses sterno-costalis IV is found, but that the latter is situated at the place of the later division between prosternum and xiphisternum. One

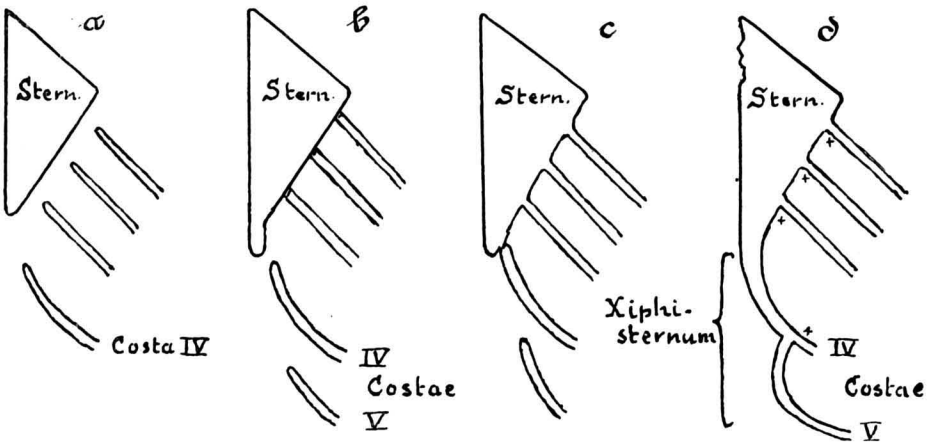

Fig. 7. Lacerta agilis. Outlines of the development of the Sternum.

may be reminded again of the fact that all syndesmoses in this region of the thoracic skeleton have been formed secundarily in places where first (7*d*) there was cartilaginous continuity. A consequence of this is also that one will never be able to tell exactly where in adult reptiles the autochthonic sternum ceases, where the ribs begin. I never saw the autochthonic sternal formation reach further caudally than the insertion of the fourth rib. On the other hand I did not see either that the fifth rib placed itself against the fourth, while the latter did not yet form a cartilaginous continuity with the sternal band. Consequently one has again to take for basis the magnitudinal relations of diagr. 7 in order to come to the conclusion, probable for an abovesaid reason as well, that the fifth rib tries to come into contact with what was formed out of the fourth rib, and not with the autochthonic sternal

formation. So, summa summarum, the sternum of the sauria consists of an autochthonic (paired) prosternum and the costal, also paired, xiphisternum, which often continues to be two xiphisterna. Of the two the autochthonic prosternum is formed first. The xiphisternum is not formed until the paired formation of the prosternum has become partially unpaired (by cranial fusion). The whole process of development of the sternum is rendered in diagr. 7; in each part of this figure the sternal formation of only one half of the body was drawn, in diagr. 7*d* half of the sternum, which is already unpaired cranially.

Now we have to consider what comparative anatomical conclusions we are brought to by the foregoing embryological facts.

According to the well known manuals on comparative anatomy by GEGENBAUR, WIEDERSHEIM and BÜTSCHLI the sternum of the tetrapode vertebrates occurs in two entirely different forms, viz. in Amphibia we find a sternum to the formation of which the very short vertebral ribs have certainly not coöperated, and in Amniota there is only a costal sternum, formed by the fusion of two so-called sternal bands, which in their turn were formed by the fusion of the ventral ends of the (vertebro-sternal) ribs. HOWES [1]) designated the sternum of the amphibians as archisternum and the sternum of the amniota he called neosternum. So in amniota the archisternum has disappeared without leaving any trace and been replaced by the neosternum. (In passing I remind the reader of the episternal elements that may have been fused with the latter). So it is a generally acknowledged fact that the amphibious sternum has another genesis than that of the amniota.

Between the sternum of the amphibians and the shoulder girdle there are various relations. In Urodela and the Anura arcifera the sternum on both sides absorbs the coracoid by diarthrosis in a sulcus articularis coracoideus, just as in the Sauria. In the Anura firmisternia on the contrary the two coracoids are joined to the sternum by synarthrosis. The two epicoracoidea, too, are here fixed to each other, so that the sternum here behaves like a caudal appendix to one solid complex, which consists of the shoulder girdles on each side. Researches into the development of the sternum of the amphibians have been made by GÖTTE and WIEDERSHEIM. According to GÖTTE [2]) the first formation of the sternum is originally paired. Afterwards it fuses into one whole with the point of the arch of the abdominal ribs.

[1]) HOWES. „Nature". Vol. 43. N°. 1108, p. 269.

[2]) GÖTTE. Entwickl.gesch. der Unke. Leipzig 1875.

The sternum of the Ranidae is supposed to have been formed out of the aforesaid paired first formation. At another place GÖTTE sums up his theories in the following way: the amphibians have no costal sternum. Its place is taken up by skeleton-parts of various origin, viz. 1°. by cartilage, formed in the linea alba abdominis and in the tendinous band of the m. rectus abdominis, which has to be considered as homologous with ventral ribs, and 2°. by cartilage formed in the membrane interepicoracoidea, there where the latter is inserted to the part spoken of sub 1°. the sternum of urodela and that of Bombinator (arcifera) consists of both parts. The sternum of the Ranidae (firmisternia) is supposed to have been formed only out of the part named sub 1°. the part formed in the membrane interepicoracoidea is considered by GÖTTE as belonging to the humeral zone.

The results of WIEDERSHEIM's researches may be summed up as follows. In the formation of the (paired) sternal formation neither in Anura nor in Urodela the humeral zone has any share. The whole development of the sternum takes place in, resp. between the muscles of the wall of the body. In the Amphibians, too, one has to speak of a costal sternum, for why should ventral parts of the myocommata that are becoming cartilaginous have to be considered from another morphological point of view than the ribs lying near the spinal column?

Let us sum up the facts found by GÖTTE and WIEDERSHEIM. In the first place the sternum is formed pairedly and in the second place it is formed loose from any previously existing skeleton-formation, in so far the theories agree. Only the interpretation of the facts is partly different. GÖTTE as well as WIEDERSHEIM speak of ventral ribs. WIEDERSHEIM brings back the whole of the amphibian sternum to ventral ribs. GÖTTE is in favour of a coracoidal origin for a large part of the sternum of the Urodela and that of Bombinator (arcifera), as well as for the whole sternum of the Ranidae (firmisternia), only because it grows in the membrana interepicoracoidea. But after all neither of these interpretations can explain away the fact that the first formation of the sternum of all amphibians if formed quite independently, in other words that it is authochthonic.

Consequently there is a genetic similarity between the sternum of the amphibians and the prosternum of the sauria; so they are homologous. The costal xiphisternum of the sauria is the ontogenetically as well as phylogenetically later formed sternal element. The value of this homology is not diminished by the fact that afterwards

in the sauria a varying number of ribs comes into contact with the prosternum, neither is it diminished by the fact that in the anura firmisternia the sternum becomes secundarily connected with the shoulder girdle. In this, as well as in the lately formed costal xiphisternum of the sauria one has to see adjustments to the further development of the anterior extremity as organ of locomotion and of support, a fact which is connected with the transition to landlife.

I am unable to find, aided by the study of the literature relating to this, further points of connection in crocodilia, aves and mammalia for the thesis developed in the preceding words.

RECAPITULATION.

1. The prosternum of the sauria is autochthonic and formed pairedly. A varying number of ribs becomes secundarily connected with the prosternum.

2. The xiphisternium of the sauria is costal and is also formed pairedly. To its formation cooperate those ribs that follow after those fixed to the prosternum.

3. The prosternum of the sauria is homologous with the sternum of the amphibians. Phylogenetically and ontogenetically it is older than the costal xiphisternum, developing in the sauria.