Anatomy. — *"The Development of the Shoulder-blade in Man".* By O. H. DIJKSTRA. (Communicated by Prof. L. BOLK).

(Communicated at the meeting of March 24, 1923).

Unlike the development of the clavicula that of the scapula has received comparatively little attention. The textbooks of anatomy (CUNNINGHAM, GEGENBAUER, RAUBER—KOPSCH, MERKEL, POIRIER—CHARPY, TESTUT) contain only general notions such as the information that the ossification of the shoulder-blade begins in the vicinity of the collum scapulae at the end of the second or in the beginning of the third month. POIRIER and CHARPY speak of an incipient ossification between the 40th and 50th day. BARDELEBEN reports a periostal ossification (such as occurs with the bones of the cranial vault) beside and under the spina scapulae at the end of the 10th week.

BRYCE alone enters into more details in QUAINS's Elements of Anatomy. According to his description the rudiment of the shoulder-blade is in the 6th week entirely cartilaginous, proc. acromialis and proc. coracoïdeus are present, but the spina scapulae is wanting. (Nevertheless BRYCE reproduces the diagram of LEWIS [1]), in which a spina is really indicated). In the 8th week ossification begins with a centre near the collum scapulae, developing into a triangular plate, at whose upper margin the spina appears in the 3rd month as a low ridge. At birth coracoid and acromion, margo vertebralis and the margin of the spina are still made up of cartilage. This description by BRYCE agrees fairly well with the one we find in BROMAN's textbook of Embryology and in that of KEIBEL and MALL, in which BARDEEN deals with this subject. BROMAN, like BRYCE, states that no spina is to be found at the cartilaginous scapula. Nonetheless he reproduces the figure of LEWIS, in which there is indeed a spina. KOLLMANN, SCHENCK, MINOT, PARKER do not speak of the first development of the shoulder-blade and only dwell on stadia of advanced ossification. In HERTWIG's Entwickelungsgeschichte BRAUS and also HERTWIG himself report a separate centre of ossification in the spina scapulae; according to the latter the spina in the neonatus still consists of cartilage sometimes; according to KÖLLIKER (quoted by BADE, Arch. f. mikr. Anat. LV) this is even always the case.

[1]) Am. Journ. Anat. Vol. 1. 1901—'02.

The most detailed report concerning the development of the shoulder-blade is that by BRYCE and BROMAN. From their figures it is evident that they derive their data from LEWIS, who published in the American Journal of Anatomy (Vol. I 1901—'02) a minute description of the development of the arm in man. Broadly stated his data agree with those of BRYCE, mentioned above. They differ, however, as to the spina scapulae. According to LEWIS the spina probably takes origin in the upper margin of the scapula. This margo superior thickens and then splits into a medial and a lateral lip. The medial lip is the future margo superior, the lateral one is the first beginning of the spina scapulae.

HAGEN [1]) describes a shoulder-blade of an embryo 17 mm. in length. The spina scapulae is absent, the proc. coracoïdeus is large, the proc. acromialis small. The latter statement cannot be reconciled with LEWIS's communication, which, on the contrary, speaks of a relatively large proc. acromialis.

This review of the literature would not be complete without mentioning the interesting study by RUTHERFORD [2]) who entered into many details of the development of the shoulder-blade. Like LEWIS he constructed wax models of the skeleton of the shoulder-girdle, and i. a. found that the spina scapulae originates in very early ossification of derivates of cartilage cells, situated between M. supra- and infraspinatus.

From this review it is clear that our knowledge of the modus of development of the shoulder-blade in man is still limited. The shape in the initial stages of development is described differently. Conflicting views are held as to the genesis of the spina and from the contents of this paper it will be seen that these are not the only points of controversy.

With a view to trace the development of the shoulder-blade in man, I constructed wax models of various stages of development. Fig. 1 represents the wax model of the shoulder-blade of the youngest embryo, 16 mm. in length. The scapula is drawn from the lateral side and from above.

The reconstruction shows:

1°. that the shoulder-blade lies in a sagittal plane, so that the lower half is in contact with the three upper ribs. Processus acromialis and clavicula are not in contact as yet.

2°. that the processus coracoïdeus is large; the processus acromialis is relatively small. The joint-cavity rests chiefly on the processus coracoïdeus.

[1]) Arch. f. Anat. u. Entwickel. Gesch. 1900.
[2]) Journal of Anatomy and Physiology 1914.

3°. There is no indication of a spina scapulae. The margo superior is neither thickened nor split into two labia.

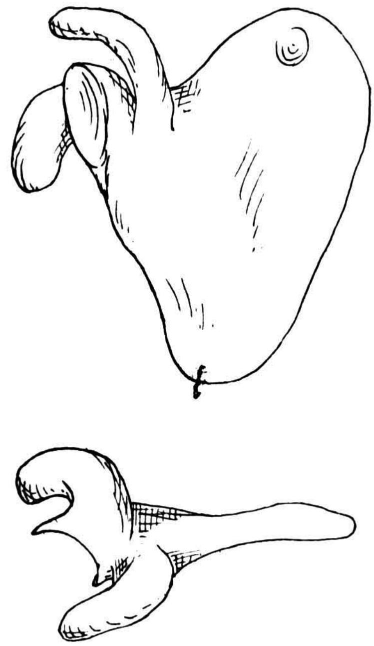


Fig. 1.

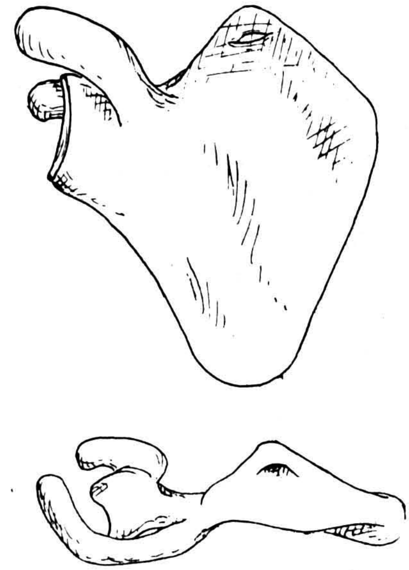


Fig. 2.

4°. The margo superior is straight, so there is no incisura scapulae.

5°. For the rest the shape of the scapula fairly well agrees with that of an adult shoulder-blade. In reconstructing the scapulae of two monkey embryos (viz. Macacus cynomolgus 17 mm. in length, and Semnopithecus maurus) it became evident that, also in these primates, the embryonic shoulder-blade already in its first beginning resembles that of the adult. Here also a spina was absent.

6°. Close beneath the angulus superior we observe a well-defined fovea where a foramen is found in older stages of development. To this we shall revert when discussing the following stage.

This stage is illustrated in fig. 2. It concerns the shoulder-blade of an embryo, 25 mm. in length. Also in this stage any indication of a spina scapulae or of a thickening of the margo superior is lacking. Nevertheless when compared with the first stage some modifications can be recognized.

1°. The shoulder-blade does not lie any more in a sagittal plane, but makes an angle with it, as is also the case with the adult. The joint-cavity lies at the level of the first rib. Acromion and clavicula have joined.

2°. The processus coracoïdeus has comparatively decreased, the processus acromialis, on the other hand, has increased. It appears, then, that the processus coracoïdeus, which is phylogenetically the oldest part, is most strongly developed in the youngest stage, whereas the processus acromialis, which is phylogenetically younger, comes more to the fore in the older stages. The joint-cavity now lies for the greater part on the planum scapulae.

3°. The margo vertebralis consists of a shorter upper portion and a longer lower portion. They are at an obtuse angle to each other.

4°. The portion of the scapula from which afterwards the fossa supraspinata develops, makes an angle with the future subspinal portion. This deviation of the upper part, which also occurs in the adult shoulder-blade (since fossa supra- and infraspinata do not lie in one and the same plane), had not yet taken place in the 16 mm. embryo.

5°. In the cranial part of the shoulder blade a foramen occurs under the angulus superior, which extends at the costal plane of the scapula as a groove along the margo superior in the direction of the joint-cavity. In fig. 3 we give a cross-section of this foramen, which is filled with connective tissue.

The existence of this foramen is no doubt surprising; yet it was not entirely unknown, as already RUTHERFORD has described it (l. c.). However, according to this author it proceeds in a groove, which reaches as far as the margo vertebralis. Now, in all the serial sections in which I also met with a groove as well as with the foramen, it proceeded along the margo superior in the direction of the joint-cavity.

RUTHERFORD explains this foramen as follows. He considers the part of the scapula, cranial to the foramen (resp. groove), as a separate piece of cartilage, which he terms *praescapula*, and which, according to his account, is connected by a strand of mesenchyma tissue with the sternal half of the clavicula. In this way he believes an inner shoulder-girdle to have developed, while he supposes the acromion-clavicula to build up the outer girdle. He adduces various arguments to prove this; however, they are weak. In my judgment the hypothesis is of no value, because a connection of the so-called praescapula with the sternal half of the clavicula does not occur. At all events in my preparations I never found a cell-strand like the one described by RUTHERFORD.

This foramen is not present in all cases. Its development also differs with various individuals, as shown by the following data. I could establish its presence either as, a true foramen, or as a deep groove in human embryos of the length of 16, 17.5, 18, 19.6, 21, 22, 25 (see fig. 3), 26, 27, 56, and 90 mm. On the other hand I did not recognize it in embryos of 12, 18, 18, 24, 26, 40, 120 mm. From this it follows that it is not infrequently absent. In some embryos the portion of the planum scapulae cranial to the foramen, i.e. RUTHERFORD's praescapula, made an angle with the rest of the planum, a fact that lends support to RUTHERFORD's view, viz. that it is really a separate piece

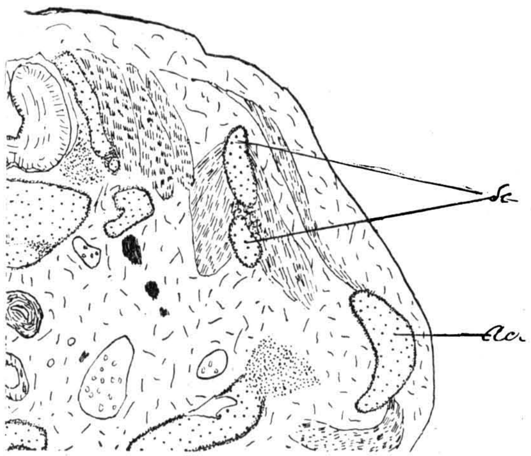


Fig. 3. Homo 25 mm. transverse. *Sc* = Scapula; *Acr* = Processus acromialis.

of cartilage. The foramen which, in young embryos, is situated rather closely to the margo superior, as observable in fig. 3, migrates in older embryos towards the margo vertebralis. Consequently RUTHERFORD's praescapula is relatively enlarged.

Now it is an interesting fact that this foramen does not occur in any other mammal, neither in reptiles, nor in amphibians. At least I never detected any. The following embryos I have examined for the occurrence of this foramen.

Semnopithecus maurus 20 mm. (C. R.)

Macacus cynomolgus 17 mm. (C. R.)

Cercopithecus 2 stages.

Sus scrofa N. T. (Keibel) 83—85, N. T. 88, N. T. 88, N. T. 91, 24 mm. (C. R.) 26 mm. (C. R.) In the last two embryos two foramina were recognized in the fossa infraspinata. It is not quite impossible that these foramina are analoga of the foramen in the human shoulder-blade.

Bos taurus 21 mm. (C. R.)

Ovis aries 19.5, 20.5, 21.5, 22.5, 23, 23.5, 26, 27, 29, 35, 45 mm. (C. R.)

Canis familiaris 12, 12, 22, 23.5 mm. (C. R.)
Sciurus vulgaris 12, 30 mm. (C. R.)
Mus decumanus 11.5, 12, 13, 13, 13.2, 14.5, 16, 18, 20, 22 mm. (C. R.)
Lepus cuniculus 17, 20 mm. (C. R.)
Spermophillus citillus 15 mm. (C. R.)
Rousettus amplexicaudatus 7.5, 10.5, 11, 11, 11.5, 12, 12, 14.5, 15,5, 16, 18 mm. (C. R.)
Talpa europea 8.5, 9, 9, 10, 12, 13, 16.5, 20 mm. (C. R).
Perameles obesula 50 mm. (C. R.)
Perameles spec. 38 mm. (C. R.)
Dasyurus viverrinus 19.6, 33, 36, 40, 53, 63 mm. (C. R.)
Sminthopsis crassicaudatus 13, 25 mm. (C. R.)
Phascalogale pennicillata 37 mm. (C. R.)
Trichosurus vulpecula 32 mm. (C. R.)
Didelphys cancrivora, 4 embryos of 25 mm. length.
Lacerta agilis N. T. (Keibel) 117, 118, 120, 123, 123, 124, 125, 126.
Calotes iubatus, length of the head $5^1/_2$ mm., 7 mm.
Lagysoma 27.5 mm.
Hemidactylus fren. length of the head 4.5 mm.
Salamandra mac. 11, 13, 15, 16, 16, 24 mm.
Pipa Americana, 12 mm.
Rana . 2 embryos.

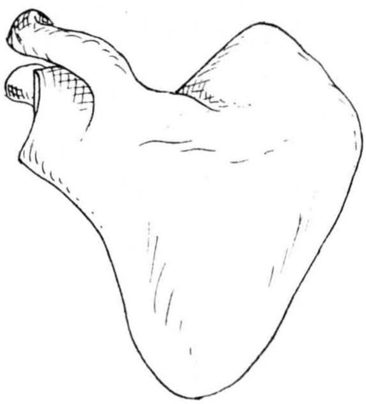
So far as I am able to judge foramina in adult shoulder-blades occur only with Homo and with various Edentata, in which they are always formed by bridging of the Incisura scapulae, and with Delphinus delphis. In the latter the character of the foramen is not known. RUTHERFORD (l. c.) has described it.

A conceivable connection, that might exist between the praescapula of RUTHERFORD and the attachment of the clavicula (not only the sternal half of the clavicula, as RUTHERFORD supposed) to the margo superior scapulae, as it occurs in reptiles, echidna and ornithorynchus, could not be ascertained, since a connection of the praescapula of RUTHERFORD to the acromial part of the clavicula could not be detected either.

It appears, then, that the foramen, present in the majority of human embryos in the cranial part of the shoulder-blade, does not occur in other vertebrates, (except in Delphinus delphis, which, however, is of such a pronounced specificity that this foramen cannot be looked upon as a homologue of that of man). Neither did I find any attachment of the praescapula of RUTHERFORD to any other skeletal bone. The significance of this foramen is unknown as yet.

As to the ossification of the scapula my experience proved it not to be so simple as is represented in the literature.

The earliest ossification I observed in an embryo of 40 mm. I constructed a wax model (fig. 4) of the scapula of this embryo.



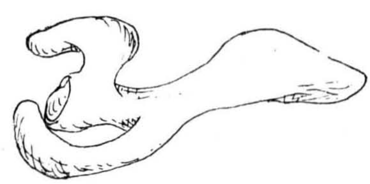


Fig. 4.

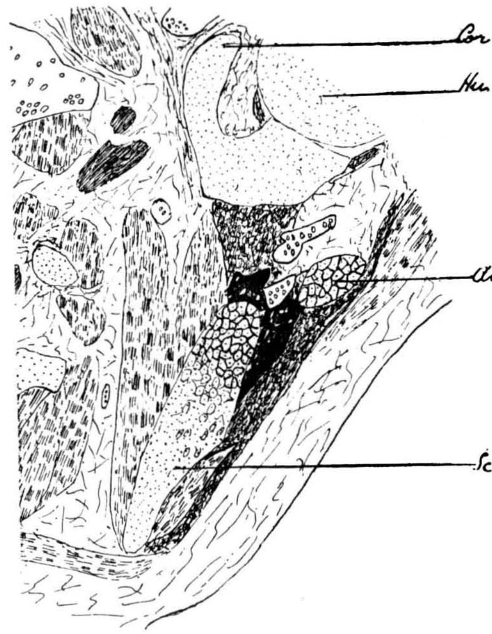


Fig. 5. Homo 40 mm. Transversal.
Cor = Processus coracoideus; *Hu* = Humerus;
Acr = Processus acromialis; *Sc* = Scapula.

Like the preceding model this also is viewed from above and from the dorso-lateral side. What this reconstructed model shows us may follow here:

The joint-cavity, lying at the level of the first rib, is now located almost entirely on the planum scapulae (as with the adult scapula). Of the spina not a trace is visible as yet, the margo superior is not thickened. To the basis of the processus acromialis an area of closely packed mesenchyma is attached, which extends between the muscular tissue and separates the rudiment of Musc. supra-, and infraspinatus.

This area of mesenchyma is cut in a cross section as represented in fig. 5. Behind the root of the processus acromialis begins a perichondrial ossification, which continues into this condensed mesenchyma. This ossification is the first formation of the spina. We see, therefore, that it is formed by a perichondrial ossification, for although no ossifying perichondrium is visible here, the fact that the bone is formed from the surrounding mesenchyma co-ossifying with cartilage, established the character of the ossification. In fig. 5 we give a cross section of this first stage of the spina.

I have not been able to recognize two centres of ossification in the cartilaginous scapula, described by RAMBAUD and RENALT (quoted by POIRIER [1]), which, according to these authors, arise between the 40^{th} and 50^{th} day and fuse in the third month.

In the scapula of an older embryo (56 mm. in length) this perichondrial ossification appears to be largely extended. The margo anterior scapulae is almost reached. The cartilage of the planum

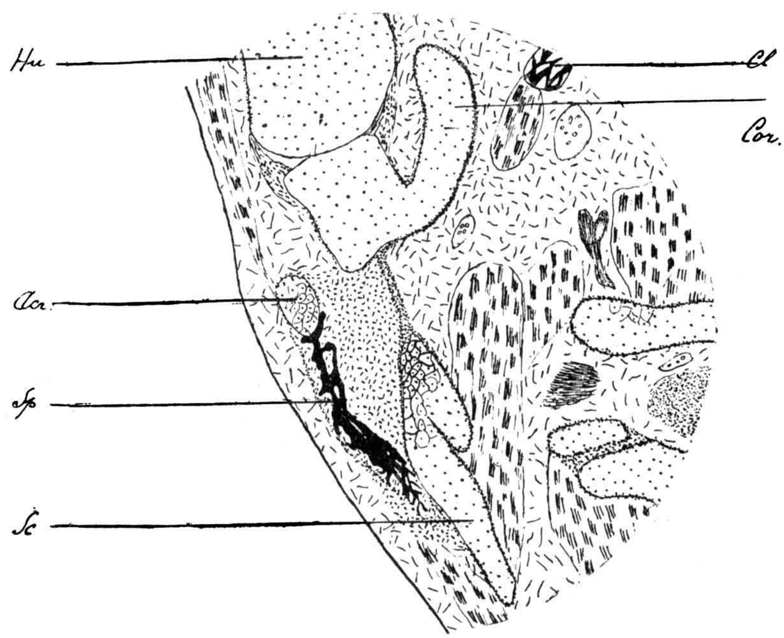


Fig. 6. Homo 56 mM. Transversal. *Hu* = Humerus; *Cl* = Clavicula; *Cor* = Processus coracoideus; *Acr* = Processus acromialis; *Sp* = Spina scapulae; *Sc* = Scapula.

scapulae, however, has been distinctly calcified over a considerable area already. The marked enlargement of the spina scapulae is shown in fig. 6. Besides the spina this figure also shows part of the foramen described above. The spina is formed by a growth of bone between

[1]) POIRIER et CHARPY, Traité d'Anatomie humaine.

M. supra- and infraspinatus, between acromion and planum scapulae. It cannot be denied, however, that in the mesenchyma, in which this bone develops, very young cartilage-cells are noticeable here and there. These cells, however, have no intermediate matter as yet; they are little differentiated and it is difficult to distinguish them from the mesenchyma-cells. So it is evident that besides bone-cells also cartilage-cells develop in the mesenchyma.

In an embryo of 90 mm. enchondrial as well as perichondrial ossification takes place, the boundary between the two being no

Fig. 7. Homo 90 mm. Margo anterior scapulae transversal.

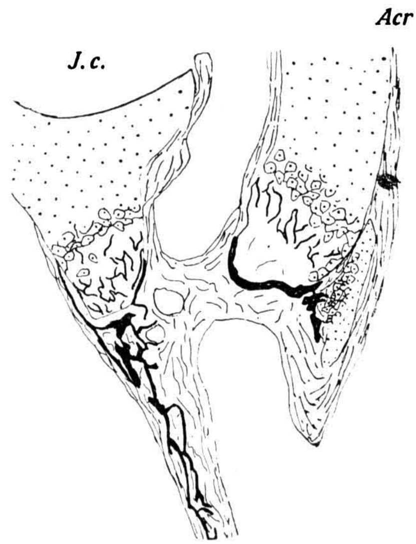


Fig. 8. Homo 90 mm. Scapula transversal *Acr.* = Processus acromialis *J.c.* = Joint-cavity. *Pl. Sc.* = Planum scapulae.

longer perceivable. The peculiar character of the perichondrial ossification along the margo anterior is remarkable. In the place of the formation of compact bone, which in other cases occurs with perichondrial ossification e.g. that of the long bones, we see here a bony framework encircled by mesenchyma. Fig. 7 shows a cross section through the margo anterior.

The study of this object (embryo of 90 mm.) shows remarkable pecularities of the growth of the spina scapulae. In the mesenchyma between M. supra- and infraspinatus a distinct cartilage is now recognizable. It is quite independent of the other mass of cartilage of the scapula. It is younger than the remaining part of the shoulder-blade; nevertheless it has already calcified to some degree and forms bone of the spina.

The cartilage has been cut in three different cross sections, as represented in the figures 8, 9 and 10. Fig. 8 illustrates a section through the scapula above the place of attachment of the processus acromialis. In the mesenchyma, which extends from the processus acromialis towards the margo vertebralis, lies the cartilage which is already partly calcified. In fig. 9 we give a section at a lower level.

The processus acromialis attaches itself at this level to the planum scapulae. Here also we observe the cartilage of the spine, independent of the remaining cartilage of the shoulder-blade. Fig. 10 shows a section through the scapula at the level of the lowest place of

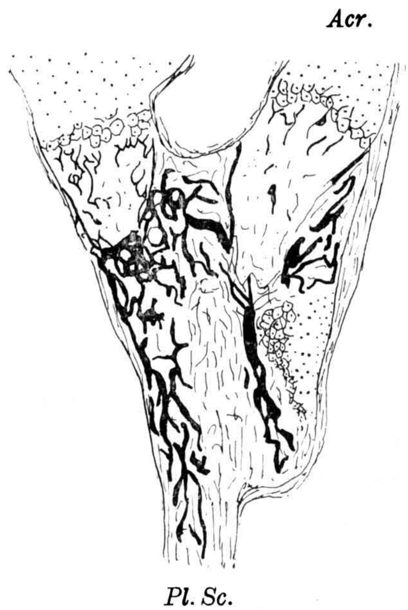


Fig. 9. Homo 90 m.m. Scapula transversal. *Acr.* = Processus acromialis. *Pl. Sc.* = Planum scapulae.

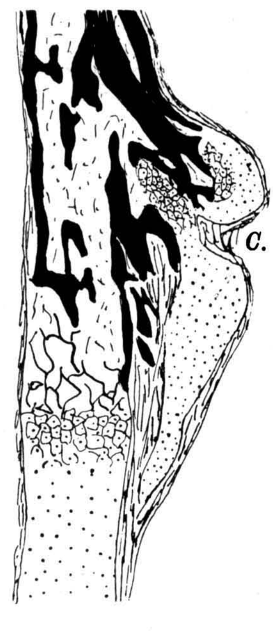


Fig. 10. 90 m.m. Scapula transversal. *C.* = cartilage of the spine. *Pl. Sc.* = Planum scapulae.

attachment of the spina. The young cartilage, which forms the spina, has here been cut over a large area. The cartilage will be seen to be partly calcified, while bone has been formed, uniting with this calcified area.

So while the first beginning of the spina is formed by perichondrial bone in the mesenchyma between M. supra-, and infraspinatus, its further development is effected by chondrial bone, which originates in the younger cartilage. This cartilage has been generated between the afore-said muscles by the same mesenchyma.

A peculiar feature is still to be observed at the shoulder-blade of the embryo of 90 mm. Bone is developed at the margo superior as well enchondrially as perichondrially. In the mesenchyma that forms the perichondrial bone, and into which this bone extends over some distance, there are two cartilaginous nuclei, made up of the same young tissue from which the cartilage of the spina has been built up. Fig. 11 shows in cross section these nuclei, which are not in contact with the remaining cartilage of the shoulder-blade. These cartilage-islets appear to be already calcified and ossified here and there. It is impossible to draw a boundary-line between the bone formed in this process and the perichondrial bone of the scapula. This ossifying process, in which (besides the enchondrial ossification of the scapula) both perichondrial and chondrial ossification of a cartilage nucleus, situated outside the perichondrial bone, are present, agrees completely with the formation of the spina scapulae. This is striking, since the spina scapulae and the definitive margo superior are the two parts of the shoulder-blade, which are missing in the first rudiment of the cartilaginous scapula. This deficiency vertebral of the place destined for the future incisure, is indeed accounted for by the fact that the margo superior in young embryos is still straight and displays no incisure. The missing parts are apparently supplied by the perichondrial bone that reaches far into the mesenchyma, together with the bone formed by the aforesaid cartilage-nuclei. At the shoulder-blade of an embryo of 120 mm· in length, in which the ossification had considerably advanced, the incisure was indeed present.

Of course, the question arises, how the cartilage of the spina as well as the cartilage nuclei are further developing. In both places the cartilage is soon transformed completely into bone. In an embryo of 120 mm. only a very few remnants of the cartilage of the spina were still left. The rest had been ossified.

After this the development of the shoulder-blade proceeds in the way described in the text-books of embryology.

Now let us review once more the current opinions of the development of the spina scapulae. It will be seen, then, that however divergent they may be, most of them cannot be deemed incorrect, when we bear in mind that they concern different stages.

Fig. 11.
Homo 90 m.m.
Margo superior scapulae transversal.

RUTHERFORD's view of the very early ossification of cartilaginous cells is no doubt correct, but holds good only for young stadia. Neither is the conception of HERTWIG and BRAUS about a separate centre of ossification quite incorrect, since there is a stage in which an independent cartilage is forming bone. BARDELEBEN's record about an ossification under and beside the spina cannot altogether be disqualified either, but it only applies to a brief stage of development. However, ossification like that of the bones of the cranial vault does not occur in the development of the shoulder-blade. In the neonatus a few cartilage may possibly sometimes be found at the spina (BRYCE), but it is certain that the spina scapulae in the new-born child does not consist of cartilage. (KÖLLIKER and HERTWIG advocate the opposite view). LEWIS's conception, however, (doubling of the margo superior) is altogether wrong. The diagram borrowed from LEWIS by BROMAN, BRYCE and BARDEEN represents a faulty reconstruction of the shoulder-blade.